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DESCRIPTIVE CATALOGUE

OF

ROCK SPECIMENS

COLLECTED BY THE

Geological Survey of Scotland,

AND EXHIBITED IN THE

EDINBURGH MUSEUM OF SCIENCE AND ART.

EDINBURGH:
PRINTED BY MURRAY AND GIBB,
FOR HER MAJESTY'S STATIONERY OFFICE.
1870.

PRICE SIXPENCE.

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PREFACE.

THE following Catalogue contains an enumeration of the rock specimens collected by the Geological Survey of Scotland, to illustrate the geology of the counties of Edinburgh, Haddington, Linlithgow, and Ayr, with portions of the counties of Lanark, Peebles, and Renfrew. The collection is increasing yearly, and, from want of space, can at present be exhibited only in part. In arranging it for exhibition, the following system is followed:—In the first place, advantage is taken of the political divisions of the country, and the specimens are grouped to represent well-marked districts. By this means, information can be most readily obtained regarding the nature of the rocks in any area. In the second place, the rocks of each large district are arranged as a series in stratigraphical order, beginning always with the oldest stratified deposits. The igneous rocks of contemporaneous origin are intercalated in their proper chronological place among the other rocks, from the formation in which they occur. Intrusive igneous rocks, the date of which is necessarily uncertain, are grouped by themselves at the end of each local series. Where metamorphosed rocks occur, they are placed after the unaltered rocks of the same formation. In a few instances the fossiliferous rocks are illustrated by some of their characteristic fossils—an arrangement which it is intended to carry out more fully when greater space can be obtained.

I have been anxious that the Catalogue should not be merely a list of specimens. Two objects seemed attainable. On the one hand, by arranging the specimens according to districts, and by inserting descriptions and sections of the geology of these districts, it appeared possible to present a tolerably complete idea of the geological structure and lithology of particular areas of the country, and thus to supplement the Maps and Memoirs of the Geological Survey. On the other hand, by furnishing a series of carefully collected specimens, and brief descriptions of them, it seemed that an amount of instruction might be given in the petrographical part of geology which could not be so readily obtained from the ordinary text-books. Whether, therefore, as illustrating the geology of the country, or as practically offering lessons in petrography, such a descriptive Catalogue appeared likely to prove useful.*

In order, however, to understand fully the geology of the districts from which this collection has been taken, reference should be made to the published maps of the Geological Survey and to the Explanations issued with the maps. A large sheet showing the area of Scotland, of which the Geological Maps on the one-inch scale have been published, is suspended in the same room with the rock-collection.

I have drawn up and added to the Catalogue a brief synopsis of the leading characters of the rocks contained in the collection. The study of petrography, however, has been so sadly neglected in this country, and so much requires to be done in chemical and microscopic analysis, that some of the identifications of the Scottish with Continental rocks must be regarded as merely provisional.

The arrangement and description of the specimens from Peeblesshire, Renfrewshire, and the eastern half of Ayrshire, from Dunlop by Kilmarnock and Sorn, to Dalmellington, also the Silurian districts of the same county, have been done by Mr. James Geikie, by whom also these districts were surveyed in the course of the Geological Survey. The other portions of the Catalogue have been prepared by myself.

ARCH. GEIKIE,
Director of the Geological Survey of Scotland.

March 1870.

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* A portion of the specimens enumerated in this Catalogue was collected in duplicate for the Museum in Jermyn Street, London ; and the description of this portion of the present collection is to some extent the same as that prepared by me for the Jermyn Street Catalogue.

CATALOGUE OF ROCK SPECIMENS.

HADDINGTONSHIRE.

[The specimens in this and the following case are entirely illustrative of the geology of Haddingtonshire, more especially of the trappean region between Haddington and Dunbar. They show that, between the deposition of the Old Red Sandstone and that of the Carboniferous Limestone, the north-eastern part of this county was the site of a long-continued series of volcanic eruptions, whereby ashes, stones, and sheets of melted lava were thrown out, which gradually accumulated to a depth of many hundred feet. The series begins at the very base of the Carboniferous rocks, above which come the tuffs with their included stones and intercalated limestone bands. These are followed by the later lava eruptions of the Garleton Hills; and, lastly, by the Carboniferous Limestone, which appears to have been deposited after the volcanic action in this district had ceased.]

Window Case, 21.

1. **Sandstone,** with annelide burrows. Bottom beds of Carboniferous series.

Near Cockburnspath.

2. **Sandstone,** with *Stigmaria* and *Lepidodendron.* Bottom beds of Carboniferous series.

Near Cockburnspath.

3. **Sandy Limestone,** with strips of large *Sigillaria,* fish remains, &c. Bottom beds of Carboniferous series.

Cove, south of Cockburnspath.

4. **Sandy Limestone,** with *Stigmaria,* &c. Bottom beds of Carboniferous series.

Cockburnspath.

5. **Sandstone,** with *Lepidodendron.* Bottom beds of Carboniferous series.

Cockburnspath.

TRAP-TUFF OR ASH OF DUNBAR AND NORTH BERWICK.

Immediately to the west of Dunbar the coast is fringed by a range of tall cliffs. They consist of stratified tuff, dull-red in colour, and roughened over with enclosed fragments which protrude from the rock in great numbers. The matrix of the tuff is highly felspathic and ferruginous, and varies in texture from a fine paste to a coarse conglomerate of sub-angular and rounded fragments. The enclosed stones are of all sizes up to masses a foot or more in diameter, the smaller pieces

Window Case, 21.

being frequently somewhat angular, while the larger bombs show a rounded outline, sometimes with a vesicular surface, indicating probably the melted condition in which they were thrown out. Although the dust and stones of which the ash has been formed were deposited at the sea-bottom, the stratification can often be seen but rudely, and on the large scale only; and in many places it can be made out merely from the lines of rounded stones which mark what was at one time the floor of the sea. The more characteristic features of the ash cannot, however, be exhibited in a collection of detached specimens, but must be studied in the field.

The Dunbar tuff is succeeded to the west by lower sandstones and shales, seen along the low flat shores at the mouth of the Tyne, where the easterly dip which they have near Dunbar is gradually reversed, until they are succeeded by another series of ash-beds on the same horizon as those of Dunbar. The coast-line for about four miles to the east of North Berwick exhibits a magnificent series of sections of tuff, with enclosed limestone seams and intruded masses of melaphyre, etc. The tuff in its lower beds has a greenish tint, getting redder in the higher parts till it acquires the same colour that characterizes the rocks at Dunbar. In this upper red zone there occurs at different localities a thin-bedded fissile grey limestone, answering closely in texture, colour, and mode of stratification, to the limestone of Burdiehouse, with which, also, it appears to correspond in geological position. No fossils have been detected in it, except some which resemble pieces of bone. Throughout the ash, fragments of ejected rock of various kinds are abundant, varying in size up to large masses from one to two yards in diameter. Sinuous veins and dykes of melaphyre, etc., also occur, traversing the contorted ash-beds in all directions.

6. **Trap-tuff** or **Ash.**

Shore cliffs, west of Dunbar.

This specimen shows the characteristic colour of the rock, and the manner in which the various lapilli are imbedded in a gravelly felspathic paste.

7. **Trap-tuff** or **Ash.**

Shore cliffs, west of Dunbar.

8. **Trap-tuff** or **Ash.**

Amisfield Mains, one mile north-east of Haddington.

This specimen illustrates a peculiar type of the ash, which is seen on the south-west side of the Garleton Hills.

9. **Compact Grey Limestone.**

Rhodes Quarry, one mile south-east of North Berwick.

This limestone occurs among the ash-beds, and attains a thickness at this locality of 30 feet. Similar seams, probably on the same horizon, are also met with further to the east, near Tantallon Castle, and also southward from Tynninghame to Traprain Law. These calcareous bands are believed to represent the Burdiehouse Limestone of Mid-Lothian.

OLD LAVAS OF GARLETON HILLS.

The ash-beds of North Berwick extend southwards for nearly three miles, and then sweep round the eastern and southern slopes of the Garleton Hills, extending as far as the town of Haddington. They are succeeded by a higher group of trappean rocks, consisting of porphyrites, etc., which have a bedded form and dip below the Carboniferous Limestone of Aberlady. These rocks are old lava streams, which, flowing out over the ash with its accompanying limestones, had hardened into solid rock previous to the deposition of the Carboniferous Limestone. The vents from which the ejected materials proceeded may perhaps be represented in part by the bosses of Traprain and North Berwick Law.

Window Case, 21.

10. Porphyrite.

South side of Hopetoun Monument.

11. Hæmatite. Iron vein now worked as an ore of iron.

Garleton Hills.

12. Porphyrite.

Peppercraig Quarry, one-quarter mile north-west of Haddington.

13. Porphyrite.

Wallace's Cave, Craigy Hill.

14. Porphyrite (Claystone Porphyry).

Score Hill, two miles north-west of Haddington.

15. Porphyrite.

Score Hill Quarry, one and a quarter mile north of Haddington.

16. Compact Porphyrite.

Quarry on turnpike road, four miles north-east from Haddington.

17. Porphyrite.

Kae Heughs.

18. Porphyrite (coarsely porphyritic).

Over Hailes Farm, four miles east of Haddington.

19. Porphyrite (partially decomposed).

One-quarter mile west from East Linton.

20. Porphyrite.

Skid Hill.

21. Porphyrite.

Quarry between Amisfield Mains and Abbey Mains, Haddington.

22. Porphyrite (amygdaloidal).

Longskelly Point, North Berwick.

23. Porphyrite.

Shore, one-quarter mile west of North Berwick.

24. Porphyrite (coarsely porphyritic).

Shore, one-quarter mile west from North Berwick.

25. Porphyrite (amygdaloidal).

Cowton Rocks, North Berwick.

26. Porphyrite (coarsely amygdaloidal).

Cowton Rocks, North Berwick.

27. Porphyrite (amygdaloidal).

Tantallan Castle.

North Berwick Law and Traprain Law are large bosses of igneous rock, which stand up conspicuously above the surrounding country, and do not form parts of any of the bedded rocks of the district. They seem, indeed, as already suggested, to be 'necks' or orifices from which the other porphyrites and ashes were thrown out, and which subsequently came to be filled up with a solid column of hardened lava. The rock in these 'necks' is often exceedingly compact, rings with a metallic sound when broken, and approaches to felstone in petrographical character.

Window Case, 21.

28. Porphyrite.

Quarry on south side of North Berwick Law.

This and the next specimen show the manner in which this rock yields to the influence of the weather.

29. Porphyrite.

Quarry on north side of North Berwick Law.

30. Porphyrite.

Traprain Law.

31. Porphyrite.

Traprain Law.

The following nine specimens illustrate the dykes which are found associated with the igneous rocks just described.

32. Porphyrite (coarsely porphyritic).

From a dyke on shore one mile west from North Berwick.

33. Porphyrite (altered).

From one of the dykes intersecting the ash at Tantallan Castle.

34. Porphyrite.

Longskelly Point, North Berwick.

35. Dolerite (altered).

East side of Belhaven Bay, Dunbar.

From a dyke intersecting Lower Carboniferous strata.

36. Melaphyre (porphyritic, with olivine).

Burning Mount, Traprain Law.

37. Melaphyre.

Chester's Quarry, four and a half miles south-east of Haddington.

38. Melaphyre (Basalt).

Dunbar Castle.

In this and the previous specimens the alteration appears to consist largely in the oxydation of the titanoferrite and the decomposition of the angite. These and other changes advance more rapidly along the sea margin, where salt water is continually thrown upon the rocks.

39. Basalt (Melaphyre) (porphyritic).

Canty Bay, North Berwick.

40. Basalt.

Bottom of cart road, Tantallan Castle.

The porphyrites of the Garleton Hills form the last of that long series of igneous rocks erupted during Lower Carboniferous times over the area of Haddingtonshire. They are succeeded by sandstones and shales with embedded plants, above which lies a series of thin limestone beds—the representatives in Scotland of the thick Carboniferous Limestone of England. Unlike those of the English formation, their organic remains are not exclusively marine, for between the limestone beds we frequently meet with coal-seams resting on fireclay, which contains the rootlets of the plants that went to form the coal. The limestones are, moreover, interbedded with sandstones and shales, wherein similar vegetable remains occur, so that in the group of strata known as the Carboniferous Limestone series of Scotland, the amount of actual limestone is comparatively small. The coast-line at Aberlady and south-east of Dunbar affords admirable sections of these deposits.

CARBONIFEROUS LIMESTONE SERIES OF HADDINGTONSHIRE.

Window Case, 21.

The following specimens, from 41 to 107, illustrate the limestones and their fossil contents, as seen to the east of Dunbar and at Aberlady. They are arranged in ascending order, beginning with the lowest limestone seen in the shore sections.

Limestone No. 1.

41. **Limestone No. 1.**
Cat Craig.
Full of *Lithostrotion irregulare.*

42. **Limestone No. 1.**
Cat Craig.

43. **Limestone No. 1.**
Cat Craig.

44. **Limestone** (lowest bed).
Garlick Rock, Aberlady Bay.
Full of *Lithostrotion irregulare.*

45. **Limestone** (lowest bed).
Aberlady Bay.
Full of *Lithostrotion junceum.*

FOSSILS FROM **Limestone No. 1.**

Window Case, 22.

46. *Spirifer trigonalis.*
Cat Craig.

47. *Productus punctatus.*
Cat Craig.

48. *Productus pustulosus.*
Cat Craig.

49. *Productus spinulosus.*
Cat Craig.

50. *Productus.*
Cat Craig.

51. *Athyris ambigua.*
Cat Craig.

52. *Athyris plano-sulcata.*
Cat Craig.

53. *Orthis resupinata.*
Cat Craig.

54. *Orthis Michelini.*
Cat Craig.

55. *Pinna.*
Cat Craig.

56. *Productus.*
Aberlady Bay.

57. *Athyris ambigua.*
Aberlady Bay.

FOSSILS FROM **Shales above Limestone No. 1.**

58. *Cyathophyllum.* Fireclay above lowest Limestone.
Cat Craig.

59. *Poteriocrinus*, stem.
Cat Craig.

60. *Lingula squamiformis.*
Cat Craig.

61. *Productus longispinus.*
Cat Craig.

62. *Productus Flemingii.*
Cat Craig.

Window Case, 22.

63. *Orthis resupinata.*
Cat Craig.

64. Spine of *Archæocidaris.*
Cat Craig.

65. *Sanguinolites.*
Cat Craig.

66. *Avicula.*
Cat Craig.

67. *Ctenacanthus?* spine.

68. *Ctenacanthus?*

Limestone No 2.

69. **Limestone,** from lower part of bed. Contains *Cyathophyllum.*

Cat Craig.

70. **Limestone,** from lower part of bed. Contains *Cyathophyllum.*

Cat Craig.

71. **Limestone,** from lower part of bed. Contains *Cyathophyllum.*
Cat Craig.

72. **Limestone.**
Shore, south-east of Dunbar.

73. **Limestone,** with *Fenestrella plebeia.*
Aberlady Bay.

74. **Limestone.** Full of *Rhynchonella pleurodon.*
Aberlady Bay.

FOSSILS FROM Limestone No. 2.

75. *Poteriocrinus,* stem.
Skateraw.

76. *Productus pustulosus.*
Cat Craig.

77. *Productus costatus.*
Cat Craig.

FOSSILS FROM Shale above Limestone No. 2.

78. *Sigillaria?*
Cat Craig.

79. *Alveolites septosa.*

80. *Spirifer trigonalis.*

81. *Productus aculeatus.*
Skateraw.

82. *Productus longispinus.*
Skateraw.

83. *Productus semireticulatus.*
Skateraw.

FOSSILS FROM Limestone No. 3.

84. *Lithostrotion junceum.*
Middle Mains, Haddington.

85. *Productus longispinus.*

86. *Productus semireticulatus.*
Longniddry.

87. *Orthis resupinata.*
Middle Mains, Haddington.

Window Case, 22.

FOSSILS FROM **Shales above Limestone No. 3.**

88. *Zaphrentis.*
Railway cutting, East Barns.

89. *Zaphrentis.*
Skateraw Harbour.

90. *Poteriocrinus.*
Skateraw Harbour.

91. *Poteriocrinus.*
Jerusalem Lime Works.

92. *Annelides.*
Skateraw Harbour.

93. *Productus longispinus.*
Skateraw Harbour.

94. *Productus longispinus.*
Railway cutting, East Barns.

95. *Productus longispinus.*
Jerusalem Lime Works.

96. *Chonetes Hardrensis.*
Railway cutting, East Barns.

97. *Rhynchonella pleurodon.*
Skateraw Harbour.

98. *Bellerophon decussatus.*
Railway cutting, East Barns.

99. *Euomphalus carbonarius.*
Railway cutting, East Barns.

100. *Nucula gibbosa.*
Railway cutting, East Barns.

101. *Nucula attenuata.*
Railway cutting, East Barns.

102. *Orthoceras.*
Skateraw Harbour.

103. *Orthoceras.*
Railway cutting, East Barns.

Limestone No. 4.

104. Limestone (coral limestone).
Torness Point, Dunbar.

105. Limestone.
Shore, south-east of Dunbar.

106. Limestone (upper beds).
Rabbit warren, east of Dunbar.

The surface of this specimen shows the *canda galli* or 'cock-tail' markings, which are believed to represent the impressions of sea-weeds.

107. Sandstone, with annelide burrows.
East of Dunbar.

108. Sandstone.
The Vaults, east of Dunbar.

Shows the cast probably of the trail of a mollusc upon soft sand.

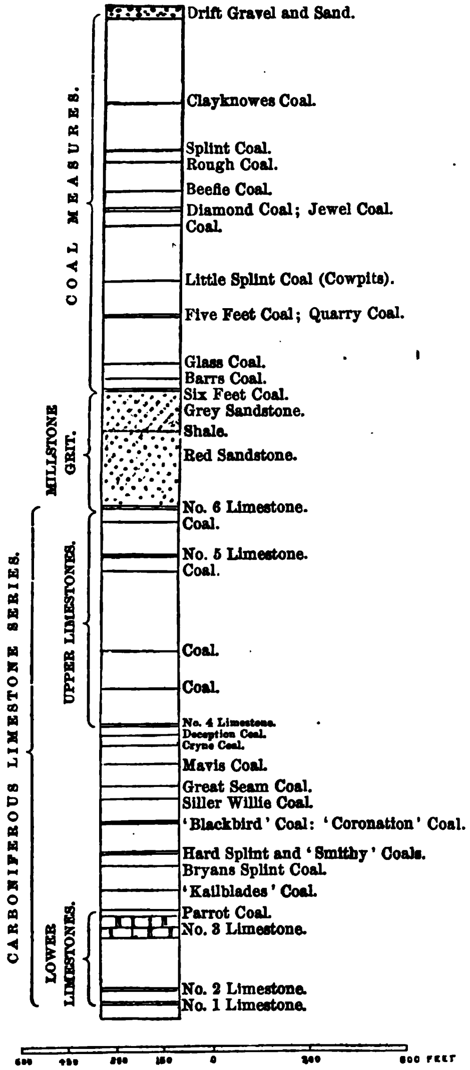
109. Limestone.
Aberlady Point.

110. Sandstone, with annelide burrows.
Aberlady Bay.

The coal-field of East Lothian belongs entirely to the Carboniferous Limestone series. The coal-seams are the same as those which form the lower part of the Mid-Lothian coal-field, the highest coal being that known as the 'Great Seam.' (See *Geological Survey Memoir on Geology of East Lothian*, p. 57.) The subjoined table shows the number and position of the workable seams in the Mid-Lothian field.

Window
Case,
22.

Vertical Section of the Mid-Lothian Coal Field.



Fossils from **Edge Coal Series.**

Window Case, 22.

111. *Lepidodendron.*
Cockenzie.

112. *Sigillaria* and linear plants.
Cockenzie.

113. *Halonia.*
Cockenzie.

114. Burrows of annelides and of bivalve shells.
Cockenzie.

Fossils from **Thin Limestones** above the Edge Coals.

115. *Poteriocrinus.*
Cuthill, Prestonpans.

116. *Archæocidaris Urii.*
Cuthill.

117. *Productus giganteus.*
Cuthill.

118. *Productus semireticulatus.*
Cuthill.

119. *Productus semireticulatus.*
Joppa.

This and one or two of the following specimens are taken from Joppa, where the upper limestones rise up again on the west or Mid-Lothian side of the coal-basin.

120. *Productus longispinus.*
Cuthill.

121. *Spirifer trigonalis.*
Cuthill.

122. *Spirifer.*
Cuthill.

123. *Sanguinolites sulcatus ?*
Joppa Quarry.

124. *Edmondia unioniformis.*
Cuthill.

125. *Bivalves ?*
Prestonpans.

126. *Bellerophon decussatus.*
Prestonpans.

127. *Euomphalus.*
Joppa.

128. *Natica*, *Archæocidaris*, etc.
Prestonpans.

129. *Pleurotomaria.*
Prestonpans.

130. *Trochus.*
Prestonpans.

131. *Trochus ?* or *Pleurotomaria.*
Cuthill.

132. *Chemnitzia gracilis.*
Prestonpans.

133. *Chemnitzia.*
Prestonpans.

134. *Murchisonia.*
Prestonpans.

135. *Murchisonia* and *Chemnitzia gracilis.*
Prestonpans.

136. *Calamites.*
West Pans.

137. Ripple-marks, with burrows of a bivalve (*Edmondia ?*)
West Pans.

Window Case, 23.

EDINBURGH AND LINLITHGOW SHIRES.

ROCKS OF PENTLAND HILLS.

The Pentlands are a chain of hills from 600 to 1900 feet high, running in a south-westerly direction from near the town of Edinburgh for about fifteen or sixteen miles, till they merge into the hills of Peeblesshire and Lanarkshire. They consist fundamentally of vertical shales and greywacke, belonging to the Upper Silurian formation. In these strata a large assemblage of fossils has been found, whence the rocks have been placed on the same horizon with the Wenlock and Ludlow series of England. The upper portions of these Silurian strata pass upward into red shales, sandstones, and conglomerates, which may represent the similar beds at Lesmahagow, forming the base of the Lower Old Red Sandstone. All these Pentland beds are inclined at high angles. On their denuded edges lies a great mass of conglomerates and grits, which have been traced by the Geological Survey for many miles to the south-west, and have now been ascertained to be an upper unconformable portion of the Lower Old Red Sandstone group.—(See *Explanation of Sheet* 24 *of the Geological Survey Map of Scotland.*) At the southern end of the Pentland Hills these conglomerates and grits attain a thickness of several thousand feet, but they rapidly thin away towards the north. Interstratified with their upper part, and piled over them to a depth of several thousand feet, occurs a great series of porphyrites, etc., disposed in regular beds with intercalated trap-tuffs and conglomerates. These igneous rocks form part of an extensive series which has now been traced by the Geological Survey from the Braid Hills even as far as the south of Ayrshire. They prove that volcanic action continued for a long time vigorous over a large part of central Scotland during the Lower Old Red Sandstone period. The Pentland chain rises out of a great plain of carboniferous rocks, which dip away from it on both sides; but it is not a mere anticlinal ridge, for the dip of the surrounding strata has been much influenced by a series of large parallel faults by which the limits of the older rocks of the hills are definitely marked.—(See the *Geological Survey Map, Sheet* 32.)

Reference to the sketch-section which accompanies the specimens in this case will illustrate the structure of the Pentland Hills. On the left or west side, the Lower Carboniferous strata (C) are seen reclining at a high angle upon the fault which has brought them down against the Silurian slates and grits (1 and 2). On the truncated edges of these latter beds rests the lowest sheet of trap (5–7), the intervening conglomerates not occurring at the point where this section crosses, though they come in in such great thickness farther south. These and the overlying trappean masses dip steadily S.E., at an average angle of about 25° to 30° across the breadth of the Pentland Hills, as far as the large fault which is traced on the Geological Survey Map as running in a south-westerly course from Portobello along the flank of the Pentland range to beyond Carlops. The trap-rocks occur in distinct beds, alternately dark and pale, so that even at some distance their true bedded form can be made out from the difference in colour which the exposed crags present. Each of these porphyrite or melaphyre beds represents a lava-flow, which was poured out over the sea-bottom during the Lower Old Red Sandstone period. The ashy layers (24, 31–2, 38–41) which occasionally separate them, mark the dust and lapilli ejected between the successive eruptions of lava; and the conglomerate bands (such as 21 and 29) point to periods of rest when the waves and submarine currents acted upon the hardened lava streams, breaking off fragments from them, and forming in this way beaches of coarse gravel and shingle, or of finer felspathic mud and sand, which vary in colour and composition with the character of the rocks whence they were derived. The history of the Pentland Hills accordingly is briefly as follows:—During the time when the Lower Old Red Sandstone was in the course of formation, the site of these hills was marked by a series of low slate islands, which the waves were ever wearing down and covering with sand and coarse shingle, represented now by the great masses of conglomerate and grit, which, at the south end of the chain, are seen to fringe round the exposed hills of slate. When the hollows between the islets had become more or less filled up, and the islets themselves, wasted by the abrading power of the sea, had probably in large measure disappeared, one or more volcanic vents opened somewhere near the north end of the range, and poured out the sheet of lava (5–7); subsequently another flow (8–9) of a different kind of rock was thrown out over the surface of the former, and the portion of it left can be traced for upwards of two miles. A pause then ensued, when the ocean recommenced the work of destruction, and formed, partly out of the subjacent lava-flows, and partly out of the sandbanks and islets not yet covered by igneous rock, a bed of sandstone and conglomerate (9a in the section). Another series of felspathic lavas (10–16) was thereafter erupted, the existing remains of which form a chain of hills about five miles long. Strata (21) consisting of felspathic grits and conglomerates indicate another pause, and a condition of things similar to that represented by the intercalation marked 9a. These sedimentary materials were eventually covered over by a stream of dark crystalline porphyrite (22), which, after a pause, marked by the felspathic, ashy, and conglomeratic beds (24), was followed by another eruption of a similar lava (25–7), which runs south to Carlops, a distance of about ten miles. Although for a long distance a bed of porphyrite may rest directly on that which lies beneath it, yet that a long pause sometimes intervened between the eruption of the two beds, is shown by the occasional intercalation of a thick mass of conglomerate and sandstone. Such interbedded deposits are often very local, as may be seen in the case of the bed from which specimens Nos. 28 and 29 were taken. After the eruption of the tuffs (31, 32), there was thrown out the great stream of light pink porphyrite (33–37) which now forms the highest peaks of the hills, and can be traced in a south-westerly direction for six or seven miles. The upper part of this bed shows indications at several points of another shower of ashy fragments (38–41), which was succeeded by a series of dark crystalline and vesicular porphyrites (42–48), forming the last of the eruptions now visible at this locality. When the igneous materials ceased to be ejected, the appearance of the district must have been widely different from what it was when they began. The islands of slate had probably been entirely covered up, either by the accumulation of their own debris, or by the volcanic matter thrown around and over them. A long bank of lava and ashes, scarcely, if at all, raised above the sea-level, occupied their site, and suffered in turn the same abrading effects from the action of the sea. In time a mass of sand and shingle, represented by the grits and conglomerates of the southern end of the Pentlands, accumulated on the site of the ancient volcano.

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Window Case, 23.

A long interval now elapsed of which we have here no geological record, save that we know that the old volcanic masses and conglomerates were elevated and suffered an extensive denudation. Thereafter the whole area underwent a gradual process of subsidence, until several thousand feet of sand, mud, lime, and peaty matter—the sandstones, shales, limestones, and coals of the Carboniferous series—had gathered over the submerged tract. In long subsequent times a re-elevation took place, denuding agencies again commenced to abrade the rising land, until the whole of the superposed Carboniferous strata, to the depth of 5000 or 6000 feet, were worn away, and the ancient lava-flows, and parts of the old slate-islands, once more appeared above the waves, to form what we now know as the chain of the Pentland Hills.

UPPER SILURIAN.

1. Sandy Mudstone.

North Esk.

This rock weathers into spheroidal pieces, and is full of fossils, as *Leptæna transversalis*, *Amphispongia oblonga*, *Platyschisma simulans*, etc. It belongs to the horizon of the Ludlow rocks.

2. Purple Greywacke, or fine-grained sandstone, full of minute false bedding.

Habbie's Howe.

This specimen is taken from one of the hard bands which are intercalated among the Upper Silurian shales of the Pentland Hills.

LOWER OLD RED SANDSTONE.

3. Green Conglomerate.

Side of River Esk, Fairliehope.

The matrix is granular, and composed chiefly of quartzose and felspathic grains. The pebbles are here small, well-rounded, and derived from the hard green greywacke of the underlying Silurian strata.

4. Greywacke or Fine Grit.

Bed of Esk, below Fairliehope.

Granular quartzo-felspathic rock, not distinguishable in hand specimens from some of the vertical Silurian greywacke which lies below. The Old Red Sandstone of the Pentland Hills has nearly always a greenish colour, corresponding to the green tint of the shales, greywackes, and grits, from the waste of which it has been derived.

Volcanic Series of the Pentland Hills, belonging to the Lower Old Red Sandstone.

[5–7. From the lowest of the volcanic series, Warklaw Hill. There are three or four distinct beds forming this hill, but they have similar characters, and are coloured as one in the section.]

5. Porphyrite.

Warklaw Hill.

A very compact dark rock from the under part of the bed.

6. Porphyrite.

North side of Torduff Reservoir.

This specimen, from a higher part of the bed, shows a granular crystalline texture, and contains specular iron.

7. Amygdaloidal Porphyrite.

North side of Torduff Reservoir.

From the highest part of the bed

showing the vesicular cavities of the upper layer of a lava stream, once filled with gas or steam, and subsequently filled up with calcedony, quartz, or carbonate of lime, carried in solution by water and deposited round the walls of the vesicles.

[8, 9. From the second trappean bed in the section, forming Torduff Hill.]

8. Porphyrite (compact felspar).

South side of Torduff Reservoir.

From under part of second bed, where the rock is darker in colour. This is the 'compact felspar' of the older Scottish mineralogists.

9. Porphyrite.

South side of Torduff Reservoir.

Light flesh-coloured dull felspathic rock, approaching a 'claystone,' with scattered crystals of felspar. Torduff Hill is entirely formed of a rock of this character, often with a mottled and brecciated appearance.

10. Porphyrite.

South-west corner of Whitehill Plantation.

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This specimen is from a group of dull red porphyritic rocks which stretch as a narrow belt along the north-west side of the Pentland Hills, and disappear beneath the mass of North Black Hill.

11. Porphyrite.

Stream south of Whitehill Plantation.

Earthy, dull, meagre, fine-grained felspathic rock. This is the kind of rock formerly known as a 'claystone.' Its earthy, meagre character is probably due to decomposition.

12. Porphyrite.

Ravine west of Green Craig.

Dull, meagre, felspathic rock, with crystals of felspar; weathers light brown. From upper part of last bed.

At the north end of the hills, above the felstone rocks just described, there is a good deal of confusion, owing to the number of small lenticular patches of different trappean beds. From the fact of the number and of the greater thickness of the igneous rocks generally towards this end of the chain, it may be inferred that in this neighbourhood lay some of the chief vents from which they proceeded. The last-named bed (11, 12) is followed at the Bonally pond by a thin seam of sandstone and conglomerate, marked 9a in the section.

13. Porphyrite.

Green Craig.

Dull-red compact crystalline rock, from one of the narrow lenticular patches at the north end of the hills.

[14–16. From bed above the conglomerates 9a in section.]

14. Porphyrite.

Glen between Belld Hill and Harbour Hill.

Dull earthy 'claystone,' mottled yellow and purple, with small black decomposing grains, perhaps of hornblende. This specimen exhibits the characteristic form of decomposition assumed by this rock.

15. Porphyrite.

From same locality.

A whiter, less decomposed rock. It weathers with a white surface, and its bleached fragments strew the hill-sides as long grey lines of rubbish.

16. Porphyrite.

North Black Hill.

A light flesh-coloured rock, very compact; breaks with a conchoidal fracture, and is closely related to felstone. The rock, in mass, is much traversed by joints, one of which is shown on the side of this specimen. Along this joint is seen the extent to which decomposition has eaten into the rock.

17. Porphyrite.

Quarry on north side of Shearer Knowe, north end of Pentlands.

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Dark-blue compact rock, with veins of carbonate of lime; breaks with conchoidal fracture, weathers greenish yellow, and resembles some of the more compact melaphyres. This specimen belongs to a higher lenticular patch at the north end of the hills, and, with the following three, passes northwards into the Braid Hills, which are a prolongation of the beds of the Pentland Hills.

18. **Trap-tuff** or **Ash.**

Roadside, quarter of a mile north of Swanston.

Felspathic rock, made up of angular fragments of different 'claystones,' chiefly of a soft white variety. This ash occupies a very limited area among the lenticular beds of the north end of the chain.

19. Mottled Porphyrite.

First Quarry west of Upper Braid.

Compact, dull, mottled 'claystone,' one of the lower beds of Braid Hills.

20. Porphyrite.

Cayiside Quarry, two miles south of Edinburgh.

This dark fine-grained rock resembles No. 17. It occurs above the ash No. 18, and appears to pass northwards into the darker traps of the Braid Hills.

21. Green Felspathic Conglomeratic Grit.

Quarry between Belld Hill and Knightfield Rig.

This rock appears to be made up in great measure of the debris of the porphyrite bed (14–16), and of the green Silurian grits. The pebbles are partly of yellow porphyrite, partly of green grit, and all well-rounded.

22. Porphyrite.

North side of north-east corner of Loganlee Reservoir.

Compact crystalline rock, veined with carbonate of lime, and speckled with hæmatite; from bed overlying No. 21, and running along the north side of the Logan House valley for upwards of four miles.

23. **Porphyrite** (Felstone).

Mouth of Howlet's House Burn.

Compact pinkish white rock; occurs in thin beds above the dark porphyrite No. 22.

24. **Trap-tuff** or **Ash.**

North-east side of Loganlee Reservoir.

This rock occurs in thin strata, consisting of fragments of different porphyrites embedded in a pale yellowish pink felspathic base. It rests immediately upon the white thin bedded porphyrite 23. Further north-east, this intercalated band becomes more conglomeratic, until it finally passes, below Castlelaw Hill, into a course conglomerate of rounded porphyrite and grit fragments.

25. Porphyrite.

South side of south-west corner of Loganlee Reservoir.

Compact crystalline rock, lying above the ash beds (24). This bed, or rather group of beds, is one of the most marked of the series; it runs from Carlops to beyond Caerketton Hill, a distance of about ten miles. In the upper part it becomes highly amygdaloidal (No. 27).

26. **Porphyrite** (Melaphyre).

Stream on the west side of Castlelaw Hill.

27. Amygdaloidal Porphyrite.

East Kipp Hill.

Chocolate-coloured rock, with numerous cavities, some of which are filled up with crystals of calc-spar, others being empty from the decomposition of the enclosed mineral. This specimen forms part of the same group as 25.

Between this and the next porphyrite are intercalated thin lenticular patches of grit and conglomerate, which appear to have filled up hollows existing on the surface of the underlying lava-flow. The next two specimens (28 and 29) illustrate these sedimentary interstratifications.

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28. Grit.

Roadside, quarter of a mile north of Carlops.

Dark quartzo-felspathic rock, scarcely distinguishable from some of the more granular porphyrites.

29. Felspathic Conglomerate.

West side of South Black Hill.

Rounded fragments of different porphyrites, etc., embedded in a granular felspathic paste.

30. Porphyrite.

Above turnpike road, a quarter of a mile north of Carlops.

Dull, compact, slightly vesicular rock, from lenticular bed among the grits and conglomerates represented by No. 28. This rock seems to be intermediate in character between the so-called 'claystones' and the ordinary porphyrites; but it is much decomposed.

31. Trap-tuff or **Ash.**

South-west side of Castlelaw Hill.

This rock is made up of a dull felspathic paste, containing angular and sub-angular fragments of pink or flesh-coloured porphyrite, ranging in texture from hornstone to claystone.

32. Trap-tuff or **Ash.**

Quarry between Scald Law and Carnethy.

From the same bed, but farther south, where it overlies the grits and conglomerates (28 and 29).

[33–37 are from the bed which forms the highest peaks of the chain, and runs from Caerketton Hill seven miles to Walstone. They are arranged to show the changes of the rock in its course along the hills.]

33. Brecciated Felstone.

Top of Caerketton Hill.

Fragments of hornstone-like felstone embedded in a looser-grained dull felstone. This brecciated appearance may be developed on weathering. From the north end of the bed.

34. Brecciated Felstone.

South-west side of Castlelaw Hill.

Collected about one and a half mile south-west of the last specimen.

35. Felstone.

Castlelaw Hill.

Very compact hornstone-like rock, from the same locality as 34. It shows the rudely schistose structure which the rock sometimes assumes.

36. Felstone.

Quarry between Scald Law and Carnethy.

White dull felspathic rock, with crystals of a black decomposing mineral, possibly hornblende. Two miles south-west of 35.

37. Felstone Porphyry.

Braid Law.

Dull earthy rock, porphyritic with decomposed hornblende (?) weathers with a rough orange-coloured surface. One and a half mile south of 36.

[38–41 illustrate an ashy layer which rests upon the last described bed of felstone (33–37). They are also arranged to show the different changes of the rock from north to south.]

38. Trap-tuff or **Ash.**

Top of Caerketton Hill, north end of range.

Angular fragments of white and pink felstone embedded in a granular felspathic matrix.

39. Trap-tuff or **Ash.**

From the same locality.

Showing angular and rounded felspathic fragments in a pinkish felspathic paste.

40. Trap-tuff or **Ash.**

Roadside north of Camp Hill, five miles south of 38 and 39.

The fragments here are mostly sub-angular, the paste being of a pinkish colour and granular texture. In hand specimens this rock much resembles some

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of the decomposing brecciated claystone-like varieties of felstone.

41. **Trap-tuff** or **Ash.**

Walstone. One mile south of 40.

The beds at this locality are finely stratified, of a light yellow colour, and nearly vertical against a large fault which skirts the whole of the south-eastern flank of the Pentlands. The thinly bedded character of the ash is shown in this specimen.

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42. **Micaceous Porphyrite.**

Quarry above Woodhouselee.

White dull rock, with crystals of orthoclase and black mica, and small granules of quartz; dendritic oxide of manganese on the joints.

[43–48 are from the dark-coloured porphyrites which overlie the Scald Law, Carnethy, and Castlelaw bed, and run from Walstone northwards for about eight miles, till lost among the upper beds of the Braid Hills, which are probably on the same horizon. It may be that there are several beds in this range, but they are so similar in composition and so obscured by the herbage and debris of the south-eastern declivities of the hills that their limits cannot be traced. The specimens are arranged to show the varieties of the rocks on this horizon, from the south end at Walstone to the north end at the Braid Hills.]

43. **Porphyrite.**

Quarry west of road between Braidwood and Walstone.

Decomposing rock with numerous crystals of decayed orthoclase (?) This rock is much less basic than the ordinary porphyrites, and approaches felstone.

44. **Porphyrite.**

North side of Camp Hill.

Dull meagre rock, finely vesicular with small scattered crystals of orthoclase. Collected about three-quarters of a mile north of 40.

45. **Sanidine Porphyrite.**

Quarry south-east side of Carnethy.

Very compact crystalline rock, with small granules of amethyst and large crystals of sanidine (a form of orthoclase felspar). These crystals have a thin tabular form, sometimes half an inch broad, and are disposed in planes which give a rudely fissile structure to the rock. Collected about a mile and a half north of the last.

46. **Porphyrite.**

East end of Hillend Hill.

47. **Amygdaloidal Porphyrite.**

East end of Hillend Hill.

Red and crystalline like 46, of which it forms an upper part; with numerous kernels of calcedony, quartz, and sometimes green earth.

48. **Porphyrite.**

Quarry on roadside south of Hillend Hill, four miles south of Edinburgh.

An upper part of same bed, showing the same red crystalline texture, all the jointed surfaces being slicken-sided and covered with a thin coating of epidote. This is the highest bed of the Pentland Hills; the next specimens illustrate rocks which seem to lie on the same horizon, and form the group of Braid Hills.

49. **Porphyrite** (Melaphyre).

Blackford Hill Quarry.

Very compact, dark, micro-crystalline rock. This is the 'clinkstone' of the older Scottish mineralogists.

50. **Porphyrite** (Melaphyre).

Blackford Hill Quarry.

50a. **Jasper** and **Hornstone.**

From vein in Blackford Hill Quarry.

51. **Porphyrite.**

Quarry west of Liberton Braid Hills.

Very compact dull 'claystone.'

CARBONIFEROUS ROCKS OF NEIGHBOURHOOD OF EDINBURGH.

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The Lower Old Red Sandstone of Mid-Lothian is covered unconformably by red and grey sandstones, which are, in all probability, the lower portions of the Carboniferous formation. The Upper Old Red Sandstone, which in Haddingtonshire and Berwickshire forms the base of the Carboniferous series, appears to be here wanting, so that the base of that series in Mid-Lothian is very irregular, according to the inequalities of the floor on which it was deposited. The lowest beds are the red and grey sandstones just referred to, which have been traced by the Geological Survey westward and south-westward over the counties of Peebles, Lanark, Ayr, and Renfrew. These strata vary greatly in thickness, but they always come in to form the basement beds of the Carboniferous system over the whole region between Dunbar and Girvan.—(See *Explanation of Sheet* 24 *of Geological Survey*, p. 13.) The Carboniferous system of Edinburghshire and Linlithgowshire is divided into the following groups:—

oal Measures.	Upper Red Sandstones. White and grey sandstones, shales, fireclays, coal-seams, etc., forming the *Flat Coal Group*.
Moor-rock or Millstone Grit.	White and grey or reddish sandstones, and some thin coals.
Carboniferous Limestone Series.	Upper limestones. Sandstones, shales, fireclays, coal-seams, etc., the *Edge Coal Group*. Lower limestones.
Calciferous Sandstones.	Sandstones, dark shales, oil shales, Houston coal, Burdiehouse limestone, with some other thin limestones. Lower Red Sandstones and cornstones.

Throughout the lower half of this formation, up to nearly the top of the Carboniferous Limestone series, contemporaneously interbedded trappean rocks are abundant. In the following collection, these rocks are inserted in their proper chronological place in the succession of strata. The collection is designed to illustrate the geology of the district between Edinburgh and Linlithgow, most of which is comprised in the *Geological Survey Map*, No. 32.

CALCIFEROUS SANDSTONE SERIES.

This series consists of two groups. Of these, the lower is composed chiefly of red and grey sandstones, with occasional conglomerates. Beds of cornstone and impure limestone also occur in it, while many of its sandy strata are themselves highly

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calcareous. Hence it received from the late Mr. Charles Maclaren the name of the Calciferous Sandstone Series. It forms the ground on which the greater part of the city of Edinburgh is built, whence it stretches southward by Craigmillar to Liberton, and south-westward along the western flank of the Pentland Hills. It rises high over the south-western part of that range forming the Cairn Hills (1839 feet over the sea), and sweeping still further southward and westward into Peeblesshire and Lanarkshire.

The upper group consists of white or grey sandstones, dark shales (often highly bituminous, and now extensively used in oil-making), fireclays, clay-ironstones, some thin coals (one of which, however, known as the Houston coal, reaches a thickness of six feet), and numerous bands of limestone, of which the most important is that known as the Burdiehouse or Queensferry bed. These various strata extend from the western and northern parts of Edinburgh westward to Linlithgow, and south-westward by the Cobinshaw Reservoir into Lanarkshire.

52. Conglomerate.

Habbie's Howe, Pentland Hills.

The pebbles are well rounded, consisting of porphyrites, felstones, jaspers, and greywackes, embedded in a granular quartzose and felspathic paste, the whole being derived from the waste of the Silurian and Old Red Sandstone strata with their overlying trappean rocks.

53. Calcareous Conglomerate.

Liberton Hill, Edinburgh.

The basis is a calcareous sand, and the pebbles, generally well rounded, consist partly of a compact cherty limestone, partly of different porphyrites, and partly of various grey micaceous grits.

54. Sandy Conglomerate.

West side of Harbour Hill, at the point marked × in the section.

The basis here is sandy, micaceous, and felspathic; the pebbles are chiefly well-rounded pieces of yellow and pink porphyrite, like that of the upper part of Harbour Hill, from which they were probably derived.

55. Sandstone.

From a higher bed at the same locality as 54.

56. Limestone.

Clubbiedean Reservoir.

57. Limestone, with *Spirorbis helicteres* (uncoiled species).

Clubbiedean Reservoir.

58. Limestone, with *Myalina*.

Clubbiedean Reservoir.

59. Shale, with *Myalina*.

Clubbiedean Reservoir.

60. Sandy Shale, with fragments of *Sphenopteris*.

Clubbiedean Reservoir.

The town of Edinburgh, as already remarked, stands upon the Calciferous Sandstone series. The strata dip eastwards, and pass under the trap-rocks of Arthur's Seat and Calton Hill, two hills of which the following specimens (61–99) are illustrative. The section accompanying the specimens is drawn through the central ridge of the town from a point west of the Castle rock to the coal-field beyond Portobello, a distance of about five miles. The lowest strata are the sandstones and shales which recline against the fault on the east side of the Castle rock. They continue with an easterly dip to Arthur's Seat, where their higher portions, retaining the same general character, are seen interstratified among different igneous rocks.

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ROCKS OF ARTHUR'S SEAT.

Arthur's Seat is the name of a hill about 820 feet high, and a square mile in extent, forming the eastern boundary of Edinburgh. It consists of two parts, separated by the deep valley of the Hunter's Bog; that to the west rises from the streets of the town in a steep slope crowned by a semicircular mural escarpment, called Salisbury Crags, which descends on the other side into the Hunter's Bog. The eastern portion of the hill is formed of successive terraces with dividing valleys, running north and south, their southern terminations being marked off by a confused pile of rock which slopes up from the north and east, and descends precipitously on the other sides. This higher part of the hill, which, seen from certain localities, looks like a great irregular cake or heap laid down upon the lower ridges, is crowned by a crag of basalt forming the summit, or Arthur's Seat proper. This peculiar contour is directly dependent upon the geology of the hill. The ridges are all of hard trap; the intervening valleys consist of softer rocks, which have yielded more readily to disintegration; while the higher irregular mass of rock at the south side belongs to a much later age, and is really what it appears to be, a newer group of crags and hummocks set down on the tops of the older ridges. The hill is thus of two distinct geological ages. The older rocks form part of the Calciferous Sandstone series, and are all inclined to the east at an average angle of about 20°. The under or westerly part consists of a set of white, red, green, and mottled sandstones, fine conglomeratic grits, coarse limestones, and red and green shales, among which are intercalated intrusive beds of dolerite, that harden and otherwise disturb the strata above and below them. The upper or eastern portion displays a great group of contemporaneous trap-rocks,—that is, melaphyres, dolerites, porphyrites, and trap-tuffs, which were ejected over the sea-bottom after the sandstones and other strata below had been deposited. All these are arranged in beds which follow with great regularity the dip and direction of the sedimentary rocks, and pass under a higher series of sandstones and shales, which underlie the Carboniferous Limestone.

The newer rocks of Arthur's Seat—viz. those which are clustered round the summit of the hill and descend to the Queen's Drive on the south side—belong to a much later period, for they rest upon the upturned denuded edges of the beds below. The older traps had been covered over by several thousand feet of newer deposits; the rocks of the surrounding country had been bent into troughs and ridges; and then the whole of this superincumbent mass had been worn away from the site of Arthur's Seat, whose trap beds again stood up as ridges, with valleys lying along the softer rocks between: all this had elapsed before the rocks of the summit and south side of the hill were ejected. From recent investigations by the Geological Survey in Ayrshire and elsewhere, there is reason to suspect that these upper and later rocks of Arthur's Seat were erupted from an isolated volcanic vent during the Permian period. The lowest, and of course oldest, of them consist of coarse volcanic

Window Case, 24. agglomerate, which lies upon the inclined edges of the dolerite and other beds below, as a great irregular mound, forming the centre and highest part of the south side of the hill. Local patches of other trappean materials occur on the top and sides of this mound, while its summit is pierced by a column of basalt, forming the crag at the top of the hill. Along the steep cliffs below the western front of this crag, a section can be seen of part of the central column in its descent through the agglomerate. Several veins, proceeding from its sides, traverse the adjacent rocks, and in one locality completely envelope a large mass of agglomerate. The arrangement of all these volcanic materials leaves little room to doubt that they were erupted from a crater of which the site is now occupied by the summit of Arthur's Seat. The agglomerate contains large masses of nearly all the rocks of the hill, and must at one time have filled up all the neighbouring valleys, and perhaps even a considerable area of the surrounding district, for only a fragment round the old crater now exists.

It thus appears that Arthur's Seat has been, at a widely separated interval, the site of two distinct volcanos : one of these was active during the Lower Carboniferous period, after the Pentland Hill craters had been long extinct ; the other, at a far later time, when the physical aspect of the country having been totally changed, a new vent burst through the deposits of the former one. After successive eruptions from this newer focus had formed a mass of rock and *débris* several hundred feet thick, represented now by the coarse agglomerate, there rose through the crater a column of melted lava, which ejected veins into the sides of the cavity. Whether or not this basalt ever flowed over from the lip of the crater and rolled down the sides of the hill as a *coulée* or lava-current, we cannot now tell. If it ever did so, the *coulée* has long since disappeared, and nothing is now left but the stump or 'neck' of basalt which rose in the pipe or orifice of the volcano, and eventually solidified there. This was the last of the eruptions which forced their way out by the central crater. There are traces, however, of what seem to have been two later eruptions, through at least one lateral fissure, where a thick bed of columnar basalt, connected with a narrow neck, overlies the agglomerate on the south side of the hill. The present contour of the hill has been in large measure determined by later denuding agencies, which have stripped off the looser parts of the cone of agglomerate, and left only the portion that was hardened round the vent. The gentle undulating valleys in the older or Carboniferous volcanic series have been anew laid bare. Glacial action has also contributed to give the rocks a smoothed and rounded form. Well-marked examples of ice-striæ are seen on the side of the Queen's Drive above Samson's Ribs and on Salisbury Crags. (See *Geology of Edinburgh, Memoirs of the Geological Survey.*)

The specimens illustrating the older series of trappean rocks of Arthur's Seat are given first in the subjoined list. As the rocks of Calton Hill are probably only a prolongation of part of these traps of Arthur's Seat, they are placed next; and then the later rocks, which are of a very much younger date, are, for the sake of local connection, ranged here immediately after the Calton and Craiglockhart Hill series.

61-62b. Porphyritic Dolerite.

Heriot Mount.

These four specimens, also Nos. 64, 65, 68, 69, illustrate the three lowest beds of trap, which are intrusive among the sandstones and shales. The rock of Heriot Mount is surmounted and underlaid by red and white altered sandstones. . The usual character of the rock is that of a rather coarsely crystalline dolerite, with disseminated crystals of a plagioclastic felspar (as in No. 61), or of augite and titaniferous iron (as in No. 61b); but in other parts it becomes much redder in colour, more compact in texture, and very sparingly porphyritic (No. 62), while some parts of the rock are veined with calcite and much red hæmatite (No. 62b).

63. Conglomeratic Sandstone.

The Hawse, Queen's Drive.

This specimen is from a bed a little way below the next bed of dolerite. Like a large number of conglomerates in the lower part of this series, it contains a considerable admixture of lime, both as limestone fragments and in the base. (See under 53.)

64. Dolerite.

Salisbury Crag.

Intruded among sandstones, shales, etc. This is the second sheet of intrusive trap.

65. Junction of Dolerite and Sandstone.

From base of dolerite, south side of Salisbury Crag.

Both rocks are much altered; the dolerite has acquired a fine texture and red colour, while the sandstone shows a vitrified aspect like quartz rock. The dolerite is marked *a*, the altered sandstone *b*.

66. Dolerite.

From dyke, cutting through dolerite of Salisbury Crag.

Full of crystals of carbonate of lime.

67. **Sandstone,** with annelide burrows.

From quarries above dolerite of Salisbury Crag.

68, 69. Porphyritic Dolerite (Melaphyre).

The Dasses.

Contains abundant felspar crystals. This is the highest of the intrusive dolerites. It forms a low irregular ridge parallel with the Hunter's Bog, and consists of several beds intruded among sandstones and shales. A short slope, probably covering similar sedimentary rocks, intervenes between this and the crag called Long Row.

Window Case, 24.

70. Dolerite.

Long Row.

Very black compact, approaching a basalt, with scattered crystals of augite, abundant titaniferous iron, and a few amygdaloidal nodules. This bed has a rudely columnar structure, and is the oldest of the contemporaneous traps. It is succeeded by beds of trap-tuff, the junction being seen on the south side of the Queen's Drive.

71. Amygdaloidal Dolerite (Melaphyre).

Below St. Anthony's Chapel.

This rock is much altered, and contains veins of hæmatite, and cavities filled with carbonate of lime, calcedony, etc. It is covered immediately by 72.

72. **Ashy Carbonaceous Shale,** or **Shaly Ash.**

Below St. Anthony's Chapel.

This bed shows the manner in which the fine dust of the volcano became mingled with the ordinary sediment of the sea-floor. It contains, in some places, ill-preserved remains of Lower Carboniferous plants and scales of *Rhizodus* (73).

73. **Ashy Carbonaceous Shale,** or **Shaly Ash,** with remains of linear plants.

Below St. Anthony's Chapel.

74. **Trap-tuff** or **Ash.**

Dry Dam.

Greenish granular rock, well stratified, containing numerous angular fragments

Window Case, 24.

of dolerite, altered shale, cherty limestone, etc., embedded in a stratified paste of comminuted dolerite.

75. Fine-grained Dolerite (Melaphyre).

Lowest bed above ash of Dry Dam.

Compact black rock, with granules of green serpentine.

76. Melaphyre.

South end of Whinny Hill.

77. Melaphyre.

South end of Whinny Hill.

78. Porphyrite.

South end of Whinny Hill.

Nos. 76, 77, and 78 were collected within a space of fifteen yards. They show the gradations between the doleritic traps, like 75, and the ordinary porphyrite, such as 79.

79. Porphyrite.

Side of Queen's Drive, east of St. Anthony's Loch.

Dull felspathic rock, with decomposed crystals of specular iron. This bed succeeds the dolerites, and seems to pass into them imperceptibly, as in 76–78. It is followed by other porphyrites, of which the next three specimens are examples.

80. Amygdaloidal Porphyrite.

Queen's Drive, east of St. Anthony's Loch.

Cavities numerous, often large, filled with calc spar, calcedony, and green-earth, generally lined with green-earth, frequently empty, and then imparting to the rock a slaggy aspect.

81. Porphyrite.

East of St. Anthony's Loch.

Red, compact, with decomposed crystals of 'ferrite' and felspar.

82. Porphyrite.

East of Queen's Drive, east end of the hill.

This is the highest visible bed on Arthur's Seat. It is darker, more homogeneous and crystalline than most of the porphyrites below, and contains minute disseminated plates of mica, and crystals of 'ferrite' and iron pyrites.

ROCKS OF CALTON HILL.

To the north-west of Arthur's Seat, from which it is separated by a deep valley, lies the conical rounded eminence called the Calton Hill. It consists of different bedded porphyrites, with intercalated seams of tuff, and corresponds closely with the eastern part of Arthur's Seat, of which, indeed, it probably forms geologically a part, the two hills being separated by a large fault. The beds marked 76 and 77 of Arthur's Seat answer to the lowest visible beds of Calton Hill 83, and the porphyrites which supervene have the same general character on both hills. The trap-tuffs of the Calton Hill have not, indeed, been detected on Arthur's Seat; but such beds, throughout the carboniferous rocks of central Scotland, are usually of very limited extent. The Calton Hill beds may be regarded, therefore, as the northward prolongations of Nos. 75–82 of Arthur's Seat, separated by a fault which has a downthrow on the north.

83. Melaphyre.

Below Regent Bridge, Edinburgh.

Lowest of Calton Hill beds. Compact fine-grained porphyritic rock, apparently intermediate in character between the dolerites and porphyrites.

84. Trap-tuff or Ash.

Below Nelson's Monument.

Stratified felspathic rock, with rounded fragments of different porphyrites, and scattered crystals of felspar.

85. Stones.

From bed of Tuff No. 84, below Nelson's Monument.

86. Trap-tuff or Ash.

Below Nelson's Monument.

Rounded and subangular fragments of different porphyrites, etc., embedded in a dull reddish granular felspathic paste. The two flat surfaces of this specimen show the thickness of a stratum of this ash.

Window Case, 24.

87. Porphyrite.

Below Nelson's Monument.

88. Stone.

From bed of ash, east of Nelson's Monument.

89. Porphyrite.

East of Nelson's Monument.

This concentrically stained compact rock forms the highest bed of the hill, and agrees closely with the highest bed of the Arthur's Seat series, as seen in the railway cutting at St. Margaret's.

ROCKS OF CRAIGLOCKHART HILL.

Craiglockhart Hill, about three miles south-west from Edinburgh, belongs to the same series of traps as Arthur's Seat and Calton Hill. It consists of a bed of trap-tuff, dipping westward, and capped by a bed of columnar melaphyre.

90. Trap-tuff or Ash.

Craiglockhart Hill.

Soft yellowish-green rock, with scattered felspar crystals. This, as well as the tuffs which succeed it westwards through Linlithgowshire, appears to be made up of a decomposed doleritic paste, in which are embedded fragments of dolerite or melaphyre, shale, sandstone, etc. The green colour is universal, and distinguishes these tuffs, as a rule, from those associated with the porphyrites, which are commonly (though by no means always) marked by deep red tints.

91. Amygdaloidal Porphyritic Melaphyre.

Craiglockhart Hill, from thick columnar bed above ash.

This rock may be compared with 76 and 83, with which it is not improbably contemporaneous. The ash (90), too, may be compared with the Arthur's Seat bed (74).

NEWER (PERMIAN ?) VOLCANIC ROCKS OF ARTHUR'S SEAT.

Window Case, 25.

92-94. Volcanic Agglomerate.

South side of Queen's Drive.

This rock consists of an irregular mass of rounded and angular blocks of different dolerites, melaphyres, porphyrites, and sandstones, sometimes several feet in diameter, embedded in a dull felspathic paste. Sometimes this paste is loose and granular, with embedded stones, as in 92; sometimes it presents a harder consistency, and contains many broken crystals of plagioclastic felspars, etc., as in 93, while at one point on the south-eastern

Window Case, 25.

declivity of the hill, the rock is as hard and compact as a melaphyre, as in 94.

95. **Stones** (fragments of amygdaloidal melaphyre), from the agglomerate.

96. **Fragment of Sandstone,** from the agglomerate.

97. **Basalt.**

Top of Arthur's Seat.

Where not weathered, this rock has a black, very compact texture; but on exposure it acquires a red tinge visible along the joints, and in spots in the interior.

98. **Porphyritic Basalt,** with large crystals of augite, and grains of olivine.

Lion's Haunch.

This bed is distinctly columnar, and seems to have proceeded from a narrow vent on the south side of the hill.

99. **Porphyrite.**

Head of Dry Dam.

This is the latest of the eruptions of which any trace remains. It seems to cover the agglomerate (92–4), and to overlap the basalt (98).

ROCKS BETWEEN EDINBURGH AND LINLITHGOW.

The next suite of specimens continues the geology of Edinburghshire, through the higher rocks of the series up to the Coal Measures of Linlithgowshire. They are arranged to show not only the different stratified rocks, but also the contemporaneous traps, as these occur in the ascending series. As already mentioned, the Calciferous Sandstone series of this region is made up of a set of white sandstones, blue and black shales, and ironstones, limestones, with occasional seams of coal. Throughout this series occur beds of stratified ash and masses of intrusive and occasionally contemporaneous dolerite. The Carboniferous Limestone series of Linlithgowshire consists of several beds of limestone intercalated between seams of trap-tuff, dolerite, sandstone, shale, coal, etc., the limestone itself being not unfrequently ashy in composition, and of a thick group of overlying coal-bearing strata, with enormous interstratified sheets of contemporaneous dolerite or melaphyre, sometimes 300 or 400 feet thick. These igneous rocks do not affect the quality of the coal, and have been bored through to reach the coal-seams, which are extensively worked below them.

CALCIFEROUS SANDSTONE SERIES.

Within the last few years the aspect of the district between Edinburgh and Linlithgow has been completely changed, owing to the working of the numerous bands of shale for the purpose of making mineral oil. The rocks are much disturbed, and their order of succession is not easily made out; but the following table* probably approximates to the true average position and thickness of the various strata that lie between the lower red group of the Calciferous Sandstones and the base of the Carboniferous Limestone series of Linlithgowshire:—

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* In this table the word 'shale' is used for convenience in the sense in which it has come to be exclusively employed in the oil districts, viz. to denote a bituminous fissile stratum from which oil can be made. When the shale is not bituminous, it passes into what is known in mining language as 'blaes.'

Window Case, 25.

TABLE OF THE CALCIFEROUS SANDSTONE SERIES.

	Fathoms.	Feet.	Inches.
Addiewell Limestone, *with main coal below, forming base of the Carboniferous Limestone series.*			
Strata	60 (?)	0	0
Shale (*upper seam or* Dam Shale *of Addiewell, also known as* Raeburn's Shale)	0	2	6
Strata	19	0	0
Shale (*seam called* Mungle's or Stewart's)	0	1	9
Strata	20–30	0	0
Coal (Two-feet *seam of Westwood*)	0	2	0
Green and red marls, etc.	30–40	0	0
Shale, *grey*	0	2	0
Strata, *with some thin coals*	10	0	0
Houston Coal	1	0	0
Strata, *principally sandstone* (the Binny sandstone group)	20–30	0	0
Shale (Fell's Seam, *or* Thick Shale *of Addiewell*) 3 feet to	1	1	6
Strata, *consisting chiefly of 'blaes,' or argillaceous shales, sandstone, fireclays, cement-stones, and thin limestone bands* (the Queensferry and Burdiehouse limestone group); *thickness not accurately known, probably at least*	40–50	0	0
Towards the bottom of the series lie shales (known as Broxburn Shales).			
Strata, *chiefly white and grey sandstones with greenish marls, 'blaes,' and limestone; thickness unknown. This series passes down into the lower red sandstone group, forming the base of the carboniferous formation.*			

indow ase, 26.

100. Brecciated Limestone.

Cock Burn, near West Brook, ten miles south-west of Edinburgh.

This specimen and 101 are illustrative of the numerous thin calcareous bands in the calciferous sandstone series of Edinburghshire.

101. Limestone.

Side of railway, Selms, Kirknewton.

102. Sandy Trap-tuff or Ash.

Bed of Linhouse Water, south end of Calder Wood, Edinburghshire.

Sandy felspathic rock, with angular pieces of shale and white felspathic lapilli.

103. Altered Shale.

Bed of Linhouse Water, below Red Craig.

This rock is traversed by a mass of melaphyre (264).

Window Case, 26.

104. Black Shale.

Hanging Craig, Granton.

Associated with the Granton and Craigleith sandstones (119, 120), there is a set of black shales, which at Wardie enclose nodules of clay ironstone, containing coprolites and other fish remains. These shales are remarkably persistent, extending southward for several miles, until they nearly reach the Pentland Hills. They are seen in the bed of the Water of Leith at Stockbridge, Slateford, Colinton, and Currie. Their fossil contents are illustrated by specimens 106–118.

105. Ironstone Nodule.

Shales, Wardie.

FOSSILS FROM THE **Wardie and Water of Leith Shales.**

106. *Adiantites Lindseæformis.* New species.

Slateford.

This unique specimen is described in the 'Geology of the Neighbourhood of Edinburgh' (*Memoirs of Geological Survey*, p. 151).

107. *Lepidodendron* with *Lepidostrobus* attached.

Slateford.

108. *Lepidodendron variabile.*

Slateford.

109. *Lepidostrobus variabilis.*

Slateford.

110. *Lepidostrobus variabilis?*

Slateford.

111. Stipes of *Lepidodendron.*

112. *Sphenopteris.*

Slateford.

113. *Sphenopteris affinis* (?), in ironstone nodule.

Granton.

114. *Posidonomya.* New species.

Slateford.

115. *Posidonomya.*

Wardie.

116. Coprolite of *Rhizodus*, in ironstone nodule.

Granton.

117. *Palaeoniscus*, in ironstone nodule.

Wardie.

118. (?) —— ironstone nodule.

Wardie.

119. White Sandstone.

Granton Point.

This rock, extensively used as a building material, forms part of a great group of white sandstones, which occupy a large part of the western area of Edinburghshire, and the contiguous portion of Linlithgowshire.

120. White Sandstone.

Craigleith Quarry.

Out of this famous quarry most of the New Town of Edinburgh has been built. The rock forms part of the same sandstone group as that of Granton.

121. Sandstone, with *Lepidodendron, Calamites*, etc.

Redhall Quarry, near Slateford.

122. Trap-tuff or **Ash.**

Lauriston Cottage, two miles west of Granton.

Compact sandy rock, with white felspathic lapilli, and irregular pieces of hardened shale.

123. Porphyrite.

Railway cutting, one and a half mile north-east of Harburn Station.

Dull compact felspathic rock, forming part of the large bed of Corston Hill. The section displayed at the railway shows several intercalations of tuff, of which 124 is a specimen.

124. Trap-tuff or Ash.

Railway cutting, one and a half mile north-east of Harburn Station.

Angular and subangular fragments of different porphyrites in a dull yellow felspathic paste. Some of the fragments are highly amygdaloidal, and show the cavities all elongated in one direction.

125. Sandstone, with iron-stains.

Bed of Linhouse Water at foot-bridge, half a mile above Camilty Bridge.

126. Quartzose Grit.

Bed of Linhouse Water, 300 yards above Camilty Bridge.

127. Trap-tuff or Ash.

Bed of Crosswood Water, Harburn Tile Works, Edinburghshire.

Window Case, 26.

Calcareo-felspathic rock; large admixture of crystalline carbonate of lime, in greenish felspathic paste.

128. Trap-tuff.

South end of Binny Craig, Linlithgowshire.

This specimen is taken from a circular patch of dull brownish black argillaceous ash, occupying the top of an anticlinal dome-shaped ridge. (Compare No. 72.) It underlies a set of calcareous shales (Burdiehouse limestone), and may be connected with a series of similar patches which, by the convolutions of the strata throughout the eastern part of this county, are found on the denuded tops of the anticlinal axes, dipping below similar shales (129).

129. Trap-tuff or Ash.

Window Case, 27.

Tor Hill, Ecclesmachan, Linlithgowshire.

Dull greenish-grey brecciated rock, consisting of angular fragments of finely amygdaloidal dolerite, embedded in a dull grey doleritic and slightly calcareous paste. The rock in mass frequently shows angular fragments of yellow baked shale and balls of different traps. It underlies a set of shales similar to those near 128.

The next important group of strata, in ascending order, illustrated by the specimens, is that of the Burdiehouse Limestone. This rock, where it occurs at Burdiehouse, four miles south-east of Edinburgh, attains a thickness of twenty-seven feet. It there has a dull yellowish or blueish-grey colour, and in certain strata has a finely striped appearance, owing to the greater or less amount of carbonaceous matter in the layers. It is compact, not crystalline, or only sparingly so in certain bands, and contains in some parts thin laminæ of coaly matter, which impart a fissile structure. Fossils are abundant, and consist of *Ferns, Stigmariæ, Lepidostrobi, Lepidodendra,* and other carboniferous plants, along with the cases of minute crustaceous animals called *Cyprids,* and teeth, scales, bones, and coprolites of several genera of fishes. The position of the limestone at Burdiehouse is about 800 feet below the Carboniferous limestone of Gilmerton,—a distance, however, which greatly varies in the districts to the west.

South of Burdiehouse, the limestone ceases to be easily traceable, owing to the depth of the covering of drift. In several of the streams which descend from the

Window Case, 27.

Pentland Hills, however, blocks of it can be seen, indicating its probable continuity southwards; and at Carlops, ten miles south of Burdiehouse, it is found among the vertical strata in the river Esk, but as two beds, four and five feet thick respectively. Its prolongation north of Burdiehouse is wholly uncertain: probably it is cut out by the great fault which, running by Liberton to Portobello, brings down the Carboniferous limestone series with its coals almost vertically against the lower red group of the Calciferous sandstones. The thickness of the rock at Burdiehouse (and also at one or two places to the west of the Pentland Hills) is exceptional, the rock there seeming to have been formed in a hollow or lagoon, which shallowed southwards,—a supposition rendered probable from the appearances presented by the rocks of Linlithgowshire.

In the eastern part of that county there occurs, at a depth of 1200 feet or more, below the Carboniferous limestone, a seam of grey compact stratified limestone, averaging about nine feet thick. In colour, texture, and fossils, it corresponds closely with the rock of Burdiehouse, of which, indeed, there can be little doubt that it is the equivalent. Along the shore, between Queensferry and Midhope Glen, where the beds undergo frequent reversals of dip, this limestone, with its associated shales and sandstones, can be seen crossing the beach five times. There it has very much the texture of the rock at Burdiehouse (see 141); but as we trace it inland it gradually becomes more argillaceous, splits up into thin layers, and passes finally into cement-stones, calcareous shales (146–7), with little resemblance to the limestone, except that they contain the same fossils. Still farther to the south, the rock regains its purity, and has been extensively worked at Dechmont; but to the south-east of that district it again becomes shaly and argillaceous, till it takes the form of fissile grey calcareous shales, whose identity with the limestone of Burdiehouse could hardly at first sight be suspected. Beyond this it re-assumes its typical character, and at Mid-Calder and Murieston occurs in great basin-shaped cavities forty to seventy feet deep. At the Mid-Calder quarries it exactly resembles some parts of the rock at Burdiehouse, being full of plants, especially of *Stigmariæ*, which spread out their long roots in regular layers, with the rootlets branching freely in all directions, as if, when the limestone existed as soft calcareous mud, the plants grew upon the spot where we now find their remains (139). From these different facts it appears that the Burdiehouse limestone was formed very slowly, probably in brackish water, across a series of lagoon-like depressions, separated from each other by muddy shoals; that in these hollows, cyprids and ganoid fishes abounded, while even the larger placoids became occasional visitors; and that in some localities there rose up from the muddy bottom a thick growth of marshy plants. The next eighteen specimens (130–147) illustrate the limestone with its shales, as developed at Burdiehouse, and as it varies in its course through the eastern part of Linlithgowshire.

130–133. Limestone.

Burdiehouse.

Nos. 130 and 131 show the usual compact grey texture of the rock, with its numerous *cyprids*, *coprolites*, and fragmentary plants. No. 132 shows the striped appearance so characteristic of the Burdiehouse limestone. Such a specimen as 132 points to slow conditions of deposit, when drifting macerated plants sank at intervals to the bottom among the calcareous mud, each layer of such vegetable detritus being marked now by a corresponding lamina of darker

Window Case, 27.

limestone. In some cases, however, the difference of tint may be owing to occasional inroads of a darker mud over the light calcareous marl at the bottom.

134. **Limestone,** with *Lepidostrobus variabilis.*

Burdiehouse.

135. **Limestone,** with *Amblypterus* (?).

Burdiehouse.

136. **Limestone,** with scale of *Rhizodus Hibberti.*

Burdiehouse.

137. **Limestone,** with scales of *Megalicthys Hibberti.*

Burdiehouse.

138. **Calcareous Shale.**

Above limestone, at Burdiehouse.

This stratum contains, in immense abundance, the cyprid cases, along with traces of plants and coprolites.

139. **Limestone.**

Raw Camps Quarry, Mid-Calder.

This specimen shows the abundant rootlets which spread through some parts of the limestone at Camps. The bed from which it is taken is now extensively worked at Camps, which is distant about eleven miles due west of Burdiehouse, on the other side of the Pentland Hills.

140. **Limestone,** with *Lepidostrobus variabilis.*

Camps, Mid-Calder.

141. **Limestone.**

Port Edgar Quarry, South Queensferry.

Black compact rock, with crystals of iron pyrites, fish scales, and plant remains. This lower part of the rock is much darker and more compact than the upper parts, which closely resemble some bands in the limestone at Burdiehouse.

142. **Black Shale.**

Above limestone, at Port Edgar.

143. **Ironstone Nodule,** containing *Amblypterus.*

From shales above Limestone, Newhalls, South Queensferry.

144. **Sandstone,** slightly calcareous.

Above shales capping the limestone, Newhalls.

145. **Coarse Shaly Limestone.**

Cutting of Edinburgh and Glasgow Railway, Priestinch, Linlithgowshire.

146. **Cement-stone.**

Priestinch, Linlithgowshire.

The two foregoing specimens (145 and 146) show the change which the limestone undergoes in its passage from Port Edgar to the south-west. The rock is an impure argillaceous limestone, with a considerable per-centage of iron, and has been burnt for a cement. The fossils in these beds are similar to those at Queensferry and Burdiehouse.

147. **Calcareous Shale,** with fish scales.

Ecclesmachan, Linlithgowshire.

The beds from which this specimen is taken lie above the tuff (129), and show the Priestinch beds in a still more argillaceous form as these pass southward. Beyond Ecclesmachan, however, they appear to become purer; for where next seen, at Dechmont, they take the typical form of a compact limestone.

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148. Brecciated Trap-tuff.

Railway Cutting, Niddry, Linlithgowshire.

Angular and subangular fragments of dolerite and pieces of shale, in a dirty green paste. The felspathic lapilli are of a light grey colour, and contain small quartz granules, with angular specks of what seems to be black shale. The rock in mass contains enormous blocks of shale, with contorted beds of shale and ironstone. (See 272.)

149. Trap-tuff.

Three hundred and fifty yards south of Dechmont House, Linlithgowshire.

White angular felspathic lapilli, in a dull blueish-black doleritic paste.

150. Trap-tuff.

Shore, a quarter of a mile east of Society, Hopetoun, Linlithgowshire.

Dull sandy rock, consisting of a doleritic base with grains of quartz, mica, etc., and fragments of dolerite.

151. Trap-tuff.

Wood, a quarter of a mile south of West Binny.

Contains subangular pale felspathic lapilli and grains of quartz, in a dull greenish-brown doleritic paste.

The next important stratum, in ascending order, is a seam of bituminous shale, which is now largely worked for oil-making in the south-eastern parts of Linlithgowshire and the adjacent portions of Edinburghshire. It is known as Fell's Shale, or the Addiewell Thick Shale. It varies in thickness up to seven feet, but its different layers are not all of equal value for the manufacture of oil.

152. Bituminous Shale (Oil-shale). Lower or Thick Seam.

Addiewell.

This seam consists of two layers, the upper and more valuable of which (two feet six inches thick) is separated from the lower (seven inches thick) by ten inches of argillaceous shale or 'blaes.' It yields 36·4 gallons of crude oil per ton of shale.

Above this shale there lies a series of strata, consisting chiefly of white and grey sandstones, of which some large beds have long been worked at Binny, whence the strata have been termed by the Geological Survey the Binny Sandstone Group. Their thickness amounts to at least from twenty to thirty fathoms.

153. Sandstone.

Binny Quarry, Linlithgowshire.

Extensively used as a finer kind of building stone.

154. Native Bitumen.

From sandstone, Binny Quarry.

This substance has probably been derived from the destructive distillation of some of the bituminous shales, or the overlying Houston Coal, owing to the intrusion of heated igneous rocks, such as the rock of Binny Craig.

155. Sandstone.

Humbie Quarry, Linlithgowshire.

White compact rock, extensively used as a building material.

156. Dolerite.

Road, 300 yards south of Newbigging Tile Works, Linlithgowshire.

This specimen is from a bed near the top of the Binny sandstone group.

Window Case, 27.

157. Dolerite.

Quarry on Peace Knowe, one mile and three-quarters south-east of Linlithgow, from bed corresponding in position to No. 156.

The Binny Sandstone Group is covered by a set of sandstones, shales, and marls, with several seams of coal, one of which has long been known as the Houston Coal. This group of strata may be termed the Houston Coal Series, and, as shown by the table on p. 25, reaches a thickness of fully seventy fathoms. It contains a valuable oil-shale called Raeburn's Shale. The next specimens (158–165) illustrate this series.

158. Concretionary Sandstone.

Cutting of Edinburgh and Glasgow Railway, Priestinch, Linlithgowshire, from bed underlying Houston Coal.

159. Coal ('Houston Coal'), altered by proximity to neck of Dolerite (276).

Railway Cutting, Craigton, Linlithgowshire.

160. Clay Ironstone in Cyprid Shale.

From beds above Houston Coal.—Old pit, south of Newbigging Tile Works, Linlithgowshire.

161. Green Clay or **'Marl.'**

Above Houston Coal, Cutting of Railway, Craigton.

This rock assumes sometimes a reddish colour, and is of a crumbling nature. It occurs all over the eastern part of the county, and is always a reliable indication of the position of the Houston Coal. The 'marls,' as they are locally termed, are from thirty to forty fathoms thick, and lie between the Houston Coal and an upper seam known as the Two-feet Coal.

162. Trap-tuff.

Wood, half a mile south of Gateside, three miles and a half east of Linlithgow.

Stratified greenish granular rock, with angular fragments of black shale and small felspathic lapilli in a light green doleritic paste.

163. Trap-tuff.

Bankhead, three miles south-east from Linlithgow.

Granular rock veined with carbonate of lime.

164. Trap-tuff or **Agglomerate.**

Stream, a quarter of a mile west of Wester Ochiltree, Linlithgow.

Coarse conglomerate of rounded nodules, chiefly dolerite, embedded in a dull granular and crumbling doleritic base.

165. Bituminous Shale ('Oil-Shale').

From Dam Shale of Addiewell. (Raeburn's Shale.)

This seam at Addiewell is two feet seven inches thick, and yields 32·1 gallons of crude oil per ton of shale.

Above the seam known as Raeburn's Shale, there lies a thickness of perhaps sixty fathoms of various sandstones, shales, clays, ironstones, and other strata, over which lies the lowest bed of the Carboniferous limestone series. Some of the sand-

Window Case, 27. stones are well seen to the east of Linlithgow. The following eight specimens (Nos. 166 to 173) are illustrative of this group of rocks, which forms the highest member of the Calciferous sandstone series.

166. Trap-tuff.

Binns Hill, Linlithgowshire.

This hill consists of a large sheet of a dull greenish dolerite-tuff or ash interbedded among the shales and sandstone above the Houston Coal. Its summit is occupied by a circular patch of basalt (167), filling up the vent from which the ash appears to have been ejected.

167. Basalt.

Top of Binns Hill, Liulithgowshire.

From neck in trap-tuff,—a black close-grained rock, containing scattered crystal of augite, and a little olivine.

168. Melaphyre.

From bed above stream, east of Longmuir Plantation, Linlithgow.

169. White Sandstone.

Kingscavel Quarry, one mile east of Linlithgow.

Extensively quarried as a building stone.

170. White Sandstone, with *stigmaria*.

Kingscavel Quarry.

171. Laminated Micaceous Sandstone.

Above 169 and 170, in Kingscavel Quarry.

172. Impure Shaly Coal.

Highest beds in Kingscavel Quarry.

173. Melaphyre.

Stream below Broomyknowes Farm, one mile and a half south of Linlithgow. From thick bed above Kingscavel sandstones.

CARBONIFEROUS LIMESTONE SERIES.

The Calciferous sandstones are followed by the Carboniferous limestone series. The latter consists of sandstones, shales, fireclays, ironstones, with a number of valuable coal-seams, and some bands of limestone. It likewise contains numerous beds of trap-tuff, dolerite, melaphyre, and other rocks of volcanic origin. The whole series is eminently characterized by the number of its igneous rocks, pointing to a period of great volcanic activity, when showers of dust and ashes and streams of lava were thrown out over a sea-bottom swarming with corals and shells. The Carboniferous limestone series of Linlithgowshire is divisible into three groups :—1*st*, A lower set of limestones with abundant tuffs and doleritic trap-rocks. 2*d*, A thick group of sandstones, shales, etc., containing a number of coal-seams and two seams of black-band ironstone. These strata form the Borrowstounness Coalfield, and the lower portion of the Bathgate Coalfield. 3*d*, The upper limestones with sandstones, etc., seen to the west of Kinneil, whence they stretch southward along the boundaries of Stirlingshire and Linlithgowshire.

Of the first or lowest group, viz. that of the thick limestones, the best sections are those laid open by the quarries among the hills, between Linlithgow and Bathgate, but particularly at the south end of these hills, along the line of quarries between Petershill and Kirkton. The limestones are there seen to be abundantly interstratified with tuffs and melaphyres. The following suite of specimens (174 to 225) exhibit these interstratifications.

Window Case, 27.

174. Limestone.

Mid-Tartraven, three miles south of Linlithgow.

Compact grey rock, with traces of shells and joints of encrinites; probably on the same horizon with the lower limestones of Kirkton (182–186).

175. Fine-grained Dolerite or Anamesite (above Limestone 174).

Mid-Tartraven.

Black, crystalline, with amygdaloidal kernels of carbonate of lime. This and the next four specimens are put along with the limestone 174 for the sake of local connection, and in order that the Kirkton beds (182–186) may be taken in uninterrupted series.

176. Trap-tuff or Ash.

Carsie Hill, one mile south-east of Linlithgow.

Dull yellowish rock, in which yellow subangular felspathic lapilli are scattered through a fine-grained dark doleritic base.

177. Trap-tuff.

Pilgrims Hill, Linlithgow.

This ash is a dull granular rock, without marked stratification, and contains, in addition to the usual lapilli of all sizes, numerous fragments of carbonized coniferous wood, some of which are seen on the present specimen. It is a prolongation of No. 176.

178. Trap-tuff.

350 yards west of Wester-Drumcross, Bathgate.

179. White Sandstone.

Hillhouse Quarry, Linlithgow.

This sandstone forms a good building stone, and overlies the tuff 176–178.

180. Basalt.

Kirkton Quarry.

From the top of a great sheet which underlies the lowest limestone of Kirkton.

181. Trap-tuff.

East Kirkton Quarry.

Loose pulverulent calcareous rock, underlying the lowest limestone of Kirkton, and resting on the basalt (180).

182. Ashy Limestone.

East Kirkton Quarry.

A mixture of trappean fragments in a base of grey limestone. A piece of fish-bone is visible at the side marked *a* on specimen.

Window Case, 28.

183. Calcareous Nodule.

From ashy bed in Kirkton limestone, a short way above the seam 182, East Quarry, Kirkton.

184, 185. Cherty Limestone.

Lower part of Kirkton limestone, East Quarry.

In 184 the cherty matter is interspersed in a curious irregular concretionary manner. In 185 the rock consists of fine laminæ alternately of silica and lime. These laminæ have, in some places, a concentric and contorted arrangement. The origin of this limestone must doubtless be connected with the action of some thermal spring, which, like the geysers of Iceland, rose in what must have been at that period a highly volcanic region, and deposited the silica and lime carried up by it in solution.

186. Upper part of **Kirkton Limestone.**

East Quarry.

Ferns and other plants occur in this limestone, along with occasional coprolites and other fish remains.

Window Case, 28.

187. Ashy Shale.

Above limestone, East Quarry, Kirkton.

This bed contains numerous well-preserved plants, as *Lepidodendron, Sigillaria, Pecopteris*, etc.

188. Porphyritic Anamesite.

Above limestone, East Quarry, Kirkton.

This rock occurs in a columnar bed resting immediately on the shale 187, and forming the highest bed visible in this quarry. From this point west to the next quarry, no rock is seen but anamesite, so that the whole space may be occupied by this bed. The dip of the rocks is westward, and the next observed bed in ascending order (189) occupies the lowest place in the Kirkton West Quarry.

189. Trap-tuff.

Below limestone, West Quarry, Kirkton.

Fine-grained dull-green rock in thin layers.

190. Limestone, with fragments of *producti* and encrinal joints.

This bed rests above the greenish ash (189), and becomes very ashy at the top.

191. Ashy Limestone, with shells and encrinal joints.

This specimen, taken from the upper surface of bed 190, contains green melaphyre *débris* interspersed through a grey crystalline limestone.

192. Calcareous Trap-tuff.

From thin bed above limestone 191.

Above this bed occur other thin limestones, intercalated among seams of tuff and ashy shale, the whole being capped by the basalt 193.

193. Anamesite (Basalt).

From columnar bed above ashes and limestones, Kirkton West Quarry.

Like most of the augitic traps in the district, this rock contains a considerable quantity of chloritic matter.

From this quarry westward to that of Petershill, where the next limestone bed is seen, no rock appears but basalt; and possibly in this case, as in 188, there may be only one great sheet of basalt intervening between the upper beds of Kirkton and the lower beds of Petershill. The excavations at Petershill form the southern termination of a great chain of quarries extending northward by Sunnyside and Silvermine to Hillend near Linlithgow. They have been opened in a bed of marine limestone, varying from between thirty and forty to seventy or eighty feet in thickness. It rests upon tuff (194) covering the basalt (193), and is succeeded by ashy beds (223, 224), sandstones, shales, and thin coals, over which lie enormous sheets of melaphyre or basalt (225, 226).

194. Calcareous Trap-tuff.

Below limestone, Sunnyside Quarry.

The upper part of this tuff, immediately below the bottom of the limestone, contains *producti* and encrinal joints.

195. Limestone.

North Mine Quarry, three miles south of Linlithgow.

Compact grey limestone with *Lithostrotion junceum*. This rock occurs in a massive bed about seventy feet thick, resting on tuff (194). The next six specimens (196–201) are from different parts of the same great bed.

196. Limestone.

North Mine Quarry.

Hard compact grey limestone with *Productus giganteus, Entomostraca*, and encrinites.

Window Case, 28.

197. Limestone, with galena and iron-pyrites.

North Mine Quarry.

The galena occurs here in detached cubes in a vein of calcspar cutting through the limestone at nearly right angles to the plane of bedding. A larger vein containing a considerable admixture of silver was formerly worked here, the name Silvermine being still applied to the quarry.

198. Limestone, consisting of a mass of the coral *Lithostrotion basaltiforme.* Some of the cavities contain **Bitumen.**

Sunnyside Quarry, one mile north of Bathgate.

199. Limestone, showing the manner in which the corals sometimes stand out from a weathered surface of rock.

Sunnyside Quarry.

200. Chert, filling and enclosing a *Productus giganteus.*

Sunnyside Quarry.

The limestone contains irregular nodular lumps of chert, sometimes ranged along the lines of bedding or interspersed through the rock. Not unfrequently, as in the present instance, the cherty matter is found filling and enveloping organic remains.

201. Limestone.

Upper part of bed, Hillhouse Quarry, one and a half mile south of Linlithgow.

The following specimens (202 to 222) illustrate the fossils which are among the more characteristic organisms of the thick limestone, and of its associated shales and sandstones:—

202. *Alveolites depressa.*
203. *Zaphrentis.*
204. *Aulophyllum fungites.*
205. *Clysiophyllum.*
206. *Lithostrotion junceum.*
207. *Poteriocrinus* (?).
208. Double annelide burrows.
209. *Athyris ambigua.*
210. *Athyris Roissyi.*
211. *Orthis resupinata.*
212. *Spirifer trigonalis.*
213. *Spirifer duplicicostata.*
214. *Strophomena crenistria.*
215. *Productus giganteus.*
216. *Productus fimbriatus.*
217. *Productus longispinus.*
218. *Productus semireticulatus.*
219. *Productus.*
220. *Bellerophon apertus.*
221. *Natica.*
222. *Cochliodus magnus.*

The thick limestone appears to have been formed during a prolonged cessation of the volcanic activity of the district. But after its formation was completed, the subterraneous forces broke out into greater activity than ever, as is shown by the extensive masses of igneous matter which lie above the thick limestone.

Window Case, 28.

223. Calcareous Felspathic Sandstone.

From hole in limestone quarry south of Knock Hill, two miles north of Bathgate.

This specimen is taken from a mass of ashy and sandy matter, with large rounded stones filling up a cavity in the limestone, which increases in width as it descends, and which may mark a volcanic 'neck.'

224. Ashy Limestone.

From hard bed in soft ash, above limestone in North Mine Quarry.

Angular fragments of green and grey felspathic matter in a base of sandy grey limestone.

225. Basalt.

From columnar bed above limestone, Hillhouse Quarry, one and a half mile south of Linlithgow.

This bed is beautifully columnar, its under surface corresponding with the bedding of the underlying strata till near the south end of the quarry, when it cuts across the beds obliquely, altering them considerably along the line of contact.

226. Melaphyre.

Immediately underlying limestone of Wardlaw Quarry.

Between the basalt of Hillhouse (225) and this melaphyre, no rock is observable except melaphyre or basalt. This specimen is from the upper part of a thick bed, and is succeeded by a limestone (227) higher in position than that of Petershill, Sunnyside, North Mine, and Hillhouse.

227. Limestone, consisting of a mass of corals (*Lithostrotion irregulare*).

Wardlaw Quarry.

This limestone is capped with shales, and a thin limestone bed, the whole being surmounted by an amygdaloidal dolerite (228) much broken by joints.

228. Altered Dolerite or **Melaphyre.**

At junction with shales, Wardlaw Quarry.

The appearance presented by this specimen resembles that of the doleritic rocks of the district, where they can be seen infringing upon other rocks, though usually they are then not quite so compact as in this specimen.

229. Dolerite.

Crag east of Witch Craig, two and a half miles south of Linlithgow.

From a bed forming part of a great sheet that overlies the Wardlaw limestone, and at one locality contains a bed of trap-tuff (230).

230. Trap-tuff or **Ash.**

Preston Burn, three-quarters of a mile south-west of Linlithgow.

Green granular felspathic rock, containing rounded fragments of different doleritic rocks, in a dull-green earthy paste. From stratified seam between beds of dolerite.

231. Dolerite.

Upper part of bed 229, above the ash 230. Kettleston Quarry, one mile south-west of Linlithgow.

232. Trap-tuff.

Lower part of Coal Measures, below Carriden House, Linlithgowshire.

233. Micaceous Sandstone, showing false bedding.

Lower part of Coal Measures, Carriden House.

234. Coarse Limestone, with encrinites.

Below Carriden House.

Window Case, 28.

Above the limestone series of the Bathgate Hills there lies a great sheet of trap (230, 231), extending northwards to Linlithgow. It is covered by the coal-bearing sandstones, shales, etc., with their interbedded igneous rocks. These strata run northwards from Bathgate, getting gradually thinner in their progress, while the traps become proportionately thicker, until in the district round Cocklerue the coal-bearing strata appear to have almost died out, their place being occupied by thin sandstones, and tuffs with great sheets of dolerite and melaphyre (235–237). North of the ridge, on the side of Bonnytoun Hill above Linlithgow, the coal series reappears, and gradually increases in thickness towards the north. It seems probable that, after the deposition of the lower limestones, a ridge of volcanic materials gradually formed between Bathgate and Linlithgow, which, increasing in extent, eventually rose above the level of the water as a low island. In the swampy marshes to the north a luxuriant vegetation sprang up, and its petrified remains now form the Borrowstounness coal-seams, while a similar growth to the south gave rise to the coal-seams of Bathgate. During the accumulation of peaty matter and silt in these two localities, streams of lava were occasionally ejected from volcanic vents between, and flowed northward to form the thick beds (241–244) of the coalfield of Borrowstounness, and the thinner ones in that of Bathgate. Over the surface of these hardened lava-flows, sand and mud silted up, forming a soil for the accumulation of new morasses, of which the remains exist in the upper coals of the two coalfields. The whole area throughout this period was undergoing a process of subsidence, until the hollows of Bathgate and Borrowstounness were filled up with sand, mud, peat, and volcanic matter, and the bottom of the water was reduced to a nearly level surface. Upon this floor, depressed considerably below the sea-level, a seam of limestone (the lower of the two upper seams) was formed, consisting in large measure of the broken stems of crinoids and pieces of shells (254). Occasional volcanic eruptions succeeded, marked now by the dolerites (255) and tuffs (256), and eventually another seam of limestone (258) gathered over the sea-bottom. Sand and mud thereafter settled down upon corals and shells, and subsequently another lava-stream (259, 260) was ejected. With this last eruption the Linlithgowshire carboniferous series, illustrated by the specimens in this case, terminates.

235–237.—Specimens from the volcanic bank which seems to have separated the coal swamps of Bathgate from those of Borrowstounness.

235. Sandstone.

Quarry at south end of Cocklerue, one and a half mile south-west of Linlithgow.

236. Sandy Calcareous Trap-tuff.

Same quarry.

Contains white felspathic fragments in a greenish-white base.

237. Dolerite.

Same locality. From bed overlying 235 and 236.

238. Dolerite.

Lower part of Coal Measures, below Carriden Manse, Linlithgowshire.

Earthy, decomposing, chloritic rock, forming a bed above 'Smithy Coal.'

Window Case, 28.

239. 'Parrot' Coal, containing impression of *Stigmaria*.

Chance Pit, Borrowstounness.

It occurs above the Carriden beds (232–234, 238), and below the thick volcanic series (241–244), which divides the coalfield into an upper and under group.

240. 'Black-band' Ironstone.

Chance Pit, Borrowstounness.

This ironstone is associated with the parrot coal (239), part of which is seen adhering to the specimen.

The Borrowstounness coalfield, as has just been mentioned, is divided into an upper and under set of strata by two sheets of melaphyre, having a united thickness of nearly 400 feet. This mass of rock seems to have flowed from the south, across the swampy morasses in which the lower coals of the district originally grew. It does not affect the quality of the seams, and throughout the coalfield the pits are sunk through the whole or part of it, to reach the coal and ironstone seams below. In the borings at the Snab Pit, which were continued to a depth of 1179 feet, no fewer than eight beds of melaphyre were passed through, having a total thickness of 468 feet. Specimens 241–244 are from this series of interbedded traps.

241. Melaphyre.

Below 'Wester Main Coal,' west side of Chance Pit, Borrowstounness.

Window Case, 29.

About the middle of this igneous mass lies a thick coal-seam, known as the Wester Main Coal, which is now exhausted. It does not occur in the west part of the coalfield, for at the Snab Pit borings no trace of it can be found, the only rock between the upper and lower zone of the volcanic series being some soft carbonaceous shale.

242. Altered Melaphyre.

Side of tramway, east of Mingle Pit, Borrowstounness, from junction with upper surface of Wester Main coal.

Soft, earthy, felspathic, finely amygdaloidal rock. This is the appearance which the augitic rocks of the carboniferous formation often assume when they come in contact with coal or bituminous shale. It is the 'white rock' of the Staffordshire collieries. (See Specimens No. 476, 477, in Window Case 42.)

243. Melaphyre.

Above Wester Main coal, tramway east of Mingle Pit.

Compact, granular, finely amygdaloidal rock, the kernels consisting of calcspar, coated with green earth.

244. Basalt.

Kipps Hill.

This rock is finely amygdaloidal, and may be a southward prolongation of the beds 241–243.

Above the thick sheets of igneous rock lies another set of coal-bearing strata, similar to that below. It contains several seams of coal and one of ironstone (245), regarded as of inferior quality to those of the under group.

245. Black-band Ironstone.

No. 23 Pit, Borrowstounness.

This seam occurs among the upper coals, and is about eighteen inches thick.

246. Carbonaceous Shale.

From beds with the ironstone 245, from same pit.

Window Case, 29.

247. Dolerite.

Capie's Point, a quarter of a mile west of Borrowstounness, from bed six to eight feet thick, among the upper group of coals.

248. Coarse Limestone.

Capie's Point; occurs a few feet above the dolerite 247.

249. Hard Fireclay.

Quarry west of Distillery, Kinneil, Borrowstounness.

This bed overlies the limestone (248), and is used for making fire-brick.

250. Gritty Sandstone.

From thick bed overlying the fireclay 249. Same locality.

251. Dolerite.

Two hundred yards south of Woodcockdale Cottage, River Avon.

This is from a bed running north by Linlithgow Bridge, and underlying the ash 252.

252. Trap-tuff.

Banks of River Avon, Little Mill, Linlithgow.

This specimen consists of small sub-angular fragments of dolerite, embedded in a greenish granular and somewhat calcareous base. It is evidently a compacted volcanic ash or fine breccia.

253. Hard Shale.

Bed of River Avon, above Woodcockdale Cottage.

The rock in mass contains numerous *Producti, Spiriferæ, Fenestellæ*, etc.

As stated after 234, the coal series of Borrowstounness is overlaid by a series of sandstones and shales, containing two seams of marine limestone. These higher strata are well displayed along the banks of the River Avon, and in the district round Carribber, whence most of the following specimens have been taken. The bed (253) occurs a few yards below the under limestone (254).

254. Compact Limestone, with iron pyrites.

Banks of River Avon, Carribber, three miles south-west of Linlithgow.

This rock is the lower of the two upper limestones.

255. Dolerite.

Three hundred yards east of Bowdenhill Farm, three miles south-west of Linlithgow.

Compact crystalline rock, from bed above lower limestone.

256. Trap-tuff.

Stream between Lochcote and Gormyre Hill, two miles south-west of Linlithgow.

Dull-greenish calcareous and felspathic rock, with fragments of different altered dolerites, etc.

257. Coarse Quartzy Sandstone or Grit.

Craigenbuck Quarry, two miles west of Kinneil, Linlithgowshire.

From thick bed underlying upper limestone.

258. Limestone, densely charged with iron pyrites.

Bowden Hill Quarry, three miles south-west of Linlithgow.

Window Case, 29. Bowden Hill, as shown in the section in the case, consists of a sheet of dolerite (259, 260) overlying the upper limestone (258a), which has been excavated in long galleries extending underneath the hill from side to side.

258a. Limestone.

Carribber Quarry, three miles south-west of Linlithgow.

Same bed as 258.

259, 260. Dolerite.

From the bed overlying upper limestone. 259 is from the banks of the Avon at Carribber; 260 from the side of Bowden Hill, above the lime quarries.

INTRUSIVE IGNEOUS ROCKS OF EDINBURGH AND LINLITHGOW SHIRES.

Throughout the lowlands of Scotland there occur numerous masses of igneous rocks which, instead of being regularly interbedded with the stratified formations, come through them more or less irregularly in a disruptive way. Sometimes they have been intruded between the planes of the strata, so that they then resemble true beds; at other times they rise as irregular bosses, without reference to any lines among the strata; while in many instances they ascend in wall-like masses or 'dykes.' Probably most, if not all, of the intrusive bosses of the district are of Carboniferous age. They consist of melaphyre, dolerite, basalt, and diorite. The numerous dykes which preserve a parallel trend towards west or north-west, are probably of Miocene age, and all consist of dolerite. (See *Explanations to Sheet 14 of the Geological Survey of Scotland,* p. 23, and references.)

261. Melaphyre.

From narrow dyke in Lower Old Red Sandstone, bed of River Esk, Fairliehope, Pentland Hills.

262. Melaphyre.

Dyke in shales, etc., western breakwater, Granton.

In this and in some of the following specimens there is evidence of much alteration of the rock. The original component minerals are in some cases hardly recognisable, while calcspar, iron-pyrites, and other secondary minerals, are more or less abundantly diffused through the rock.

263. Melaphyre.

Dyke in bed of Linhouse Water, near south end of Calder Wood, Mid-Calder.

264. Melaphyre.

Dyke in bed of Linhouse Water, below Red Craig.

265. Melaphyre.

Dyke in shale at St. George's Well, Water of Leith.

266. Melaphyre.

Dyke on shore at Newhalls, South Queensferry.

267. Melaphyre.

Blackness Castle, Linlithgowshire.

268. Highly altered Melaphyre.

Dalmeny Church, Linlithgowshire.

Window Case, 29.

269. Altered Melaphyre.

From dyke in bed of stream above East Kinleith, five miles south-west of Edinburgh.

270. Altered Melaphyre.

From dyke, western breakwater, Granton.

271. Melaphyre.

Newlands, Kirknewton.

272. Altered Dolerite.

From intrusive knob in tuff, one hundred yards north of Niddry Castle, Linlithgowshire.

Much calcspar is diffused through this specimen.

273. Dolerite.

West of Port Edgar, Linlithgowshire.

274. Dolerite.

Hall Craigs, Kirknewton.

275. Dolerite.

Dalmahoy Hill.

276. Dolerite.

Craigton Hill, Linlithgowshire.

277. Dolerite.

Selms Tops, Kirknewton.

278. Dolerite.

Bell's Mill, Stockbridge, Edinburgh.

279. Dolerite (in shale).

West Broadlaw, three miles south-east of Linlithgow.

In this, and a number of the other dolerites of Linlithgowshire, there is a marked proportion of petroleum diffused through the base. When a fresh fragment is broken off, the odour of petroleum is distinctly perceptible. The same odour and a quantity of water are given off still more abundantly when the powder of the rock has been heated in a closed tube. Sometimes drops of liquid petroleum are found in cavities of the dolerites. These rocks have not yet been analyzed.

280. Dolerite.

Dechmont Law, Linlithgowshire.

This rock emits the same odour as No. 279.

281. Dolerite.

Quarry on roadside between Clinkingstane and Wester Drumcross, Linlithgowshire.

Gives off the same odour as 279 when freshly broken.

282. Dolerite.

Plantation north of Balgreen, three miles south-east of Linlithgow.

Gives off same odour as No. 279.

283. Dolerite.

Faugh Hill, Mid-Calder Parish.

284. Dolerite.

Binny Burn, three miles south-east of Linlithgow.

285. Dolerite.

Quarry south end of Glenpuntie Wood, Cramond.

Window Case, 29.

286. Dolerite.

Shore at the Tombstone, west of Granton.

287. Altered Dolerite.

Carmel Hill, Kirkliston.

Much carbonate of lime is diffused through this rock.

288. Dolerite.

Ratho Quarry, Edinburgh.

289. Dolerite (?).

From vein traversing the rock of Ratho Quarry, Edinburgh.

290. Anamesite.

South end of Binny Craig, Linlithgowshire.

This close-grained rock, when freshly broken, emits an odour like that given off by No. 279. At one part of Binny Craig, aggregations of bitumen are found in cavities of the rock.

Windo Case, 30.

291. Anamesite.

Quarry south of Dalmeny Church.

292. Basalt. ('Basaltic clinkstone.')

Castle Rock, Edinburgh.

293. Amygdaloidal Melaphyre (altered).

Near Dechmont House, Linlithgowshire.

294. Amygdaloidal Melaphyre.

From dyke, bed of River Esk, below Carlops.

295. Amygdaloidal Melaphyre (altered), veined with calcedony, the cavities lined with calcedony and quartz-crystals, and often filled with asphaltum.

Roadside between the Knock and Limefield, Bathgate.

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296. Diorite.

Lindsay's Craigs, Kirkliston.

Numerous small plates of biotite or magnesia-mica are scattered through this rock.

297. Diorite.

Road at Crossall Hill, one mile east of South Queensferry.

In this beautiful rock the hornblende is well marked, and is traversed by minute needles of another mineral; small scales of biotite are dispersed through the base.

298. Diorite.

Dundas Hill, Dalmeny.

299. Diorite.

Corstorphine Hill.

300. Diorite.

Corstorphine Hill; from the lowest part of the rock at the quarry on the north end of the hill.

301. Diorite.

Corstorphine Hill.

Containing a cavity filled with *prehnite.*

302. Diorite.

North end of Craigie Hill, six miles west of Edinburgh.

Window Case, 30.

SPECIMENS ILLUSTRATING THE ALTERATION OF SEDIMENTARY ROCKS BY ROCKS OF INTRUSIVE ORIGIN.

303. Junction of Anamesite and Limestone.

From the side of a dolerite dyke traversing the limestone quarry of Camps, Mid-Calder.

304. Junction of Anamesite and Sandstone.

From the bottom of the dolerite bed of Salisbury Crags, Edinburgh. (See also No. 65, Window Case 24.)

DOLERITE DYKES FROM THE EAST AND WEST SERIES.

305. Dolerite.

Dyke at the Knock, two miles north of Bathgate.

306. Dolerite.

Dyke at cottage south of the Knock, two miles north of Bathgate.

307. Dolerite.

Dyke at Lower Craigmailing, two and a half miles south of Linlithgow.

308. Dolerite.

Dyke at Walton Farm, two miles north of Linlithgow.

309. Dolerite.

Dyke at Nancy's Hill Quarry, one and a half mile east of Linlithgow.

This dyke runs nearly east and west for a distance of more than four miles, till it enters the county of Stirling. It traverses the upper part of the calciferous sandstone series, and the carboniferous limestone group, with its limestones, coals, and thick doleritic masses. Yet even where it runs through these carboniferous dolerites, it retains its distinctness as markedly as among the sandstones and other strata. No. 309 is taken from the eastern end of the dyke, where it pierces the Houston Coal series. The next two specimens are from more westerly parts of the same dyke.

310. Dolerite.

Dyke at Avon Aqueduct, Linlithgowshire.

From same dyke as Nos. 309 and 311. This specimen is finely amygdaloidal, the cavities being filled with calcspar and amethyst.

311. Basalt.

Dyke at Hiltly Cottage, one mile south of Linlithgow.

From same dyke as Nos. 309 and 310, but much closer in texture, the component minerals of the rock being no longer recognisable.

312. Dolerite.

Dyke at Kipps, one and a half mile south of Linlithgow.

This dyke traverses the carboniferous limestone series, and its associated igneous rocks.

313. Dolerite.

Dyke at Beecraigs, two miles south of Linlithgow.

314. Dolerite.

Dyke at Currie, five miles south-west of Edinburgh.

Contains small kernels of calcspar.

315. Dolerite.

Dyke at Green Burn, Dalmahoy, Edinburgh.

Window Case, 30.

316. Dolerite.
Dyke at Albany Street, Edinburgh.

317. Dolerite.
From the long dyke, Longniddry, Haddingtonshire.

SPECIMENS FROM BOULDERS IN THE DRIFT OF THE NEIGHBOURHOOD OF EDINBURGH.

Overlying all the rocks which have been described in the foregoing pages, there is spread a thick series of clays, sands, and gravels, to which the name of Drift has been given. These deposits are the record of a time when Scotland, along with a great part of Europe, was cased in snow and ice, as Greenland is now. The lowest member of the group is known as the Boulder-clay, and consists of coarse unstratified clay full of stones, and often containing intercalated sands and stratified clays. The boulder-clay has been mainly formed by the grinding action of large masses of land-ice as they moved over the country from a higher to a lower level. It is made up chiefly of the broken fragments and detritus of the rocks of each district where it occurs, but it usually contains also a small proportion of stones which have travelled some distance. As a rule, the boulders which have come the longest way are fewest in number and smallest in size. Their surfaces are almost always covered with scratches and groovings formed by the friction of grains of sand and fragments of rock as the stones were pushed along under the ice. Above the boulder-clay, or interstratified in its higher parts, lie some deposits of fine clay and sand, through which are scattered here and there boulders and small gravel. These clays have been formed under the sea, for marine organisms occur in them. That there was abundance of drift-ice floating over the sea at the time, is shown by the occurrence in those clays of striated boulders, which could only have been dropt into fine silt by the melting of masses of ice on which they had been floated off from the land. The existence of drift-ice seems likewise to be indicated by the remarkable way in which the clays and sands are contorted (as at Portobello), as if by having been forced along the sea-bed under the pressure of large masses of stranding ice.

The following specimens illustrate the character of the stones in the boulder-clay and the marine-clays, and show the direction in which the land-ice of the first period and the drift-ice of the second period moved. Nos. 319 to 350 were obtained from cuttings in the boulder-clay for the erection of the new poorhouse at Craiglockhart. Out of 100 specimens of the boulders selected at random from these cuttings, the following Table was constructed:—

I. Stones derived from the immediate district, 88 per cent.	White Sandstone,	23 per cent.	
	Red Sandstone,	10 ,,	
	Trap-tuff (Craiglockhart Hill),	8 ,,	
	Melaphyre, Dolerite, etc.,	40 ,,	
	Diorite,	5 ,,	
	Carboniferous Limestone,	1 ,,	
	Queensferry Limestone,	1 ,,	
			— 88 ,,
II. Stones which must have travelled under the ice for 25 miles, and some of them probably much farther, 12 per cent.	Red Grit,	2 ,,	
	Coarse Red Conglomerate,	1 ,,	
	Quartz Pebble (from Conglomerate),	1 ,,	
	Red Porphyrite,	6 ,,	
	Mica-schist,	1 ,,	
	Granite,	1 ,,	
			— 12 ,,
			—— 100 per ct.

From this Table it will be seen that 88 per cent. of the boulders have been derived from rocks which lie in the immediate neighbourhood to the west and north-west of Craiglockhart; that 10 per cent. cannot have come from any nearer source than the Ochil Hills, a distance of twenty-five miles; while 2 per cent. have travelled trom the metamorphic hills of the Highlands, the nearest of which are fully forty miles off.

Window Case, 30.

The specimens from Nos. 351 to 358 show the character of the stones which are sparingly scattered through the marine or brick clays of Portobello. In this series, also, there is evidence of a transport of materials, not only and chiefly from the west, but also to a small extent from the north or north-east. Nos. 352 to 357 belong to the rocks which lie in the carboniferous tracts westwards from Edinburgh. No. 355 may be traced to the hills at South Queensferry. Nos. 352 to 355 have probably been moved from some part of Linlithgowshire. No. 351 must have come from the Highland mountains. The specimen No. 358 is of chalk, and similar fragments occasionally occur in the upper clays, even as far south as the coasts of Northumberland and Durham. No chalk now occurs *in situ* in Scotland, though, from the abundance of flints and other evidence in Banffshire and Aberdeenshire, there is reason to suppose that a portion of the chalk formation may exist under the Moray Firth and adjacent portions of the North Sea. The chalk fragments in the drift-clays of Mid-Lothian, probably either came from this area, or even from Denmark or the south of Scandinavia, where the chalk is still found. Hence, while the chief trend of the floating ice was eastward or south-eastward from the Highland mountains across the submerged plains of the midland counties, there were nevertheless occasional stray ice-floes, which found their way from the north of Scotland or from Scandinavia, and dropped their frozen sand and stones over the basin of the Firth of Forth. Nos. 360, 361 exhibit specimens of the minute forms of marine organisms which are found in the brick-clays. The skeleton of a seal was obtained from the Portobello clays a few years ago. From some of the higher parts of the clays, hazel-nuts, with other drifted land vegetation (359), and shells of *Scrobicularia piperata*—a mollusc still living in the estuary of the Forth—have been obtained.

318. Striated Stone. From boulder-clay.

North Medwin Water, Lanarkshire.

The following thirty-two specimens were obtained from the cuttings in boulder-clay made for the new poorhouse at Craiglockhart, near Edinburgh. Nos. 319 to 327 inclusive have been derived from the rocks of the Highlands. Nos. 328 to 335 have, in all likelihood, come from the Lower Old Red Sandstone series of the Ochil Hills. Nos. 336 to 350 are from the Carboniferous area which stretches westward from Edinburgh through Linlithgowshire and Stirlingshire, to the base of the Old Red Sandstone hills.

319. Grey Granite.

The nearest place from which such a rock could have come is some part of the south-western Highlands.

320. Quartz Rock.

From the altered Lower Silurian rocks of the Highlands.

Window Case, 30.

321. Quartz Rock.

Altered Silurian rocks of Highlands.

322. Gritty Quartz Rock.

Altered Silurian rocks of Highlands.

323. Metamorphic Grit.

Altered Silurian rocks of Highlands.

324. Pebbly Greywacke or **Grit.**

Altered Silurian rocks of Highlands.

325. Fine Brecciated Conglomerate.

Altered Silurian rocks of Highlands.

326. Schistose Greywacke.

Altered Silurian rocks of Highlands.

327. Mica-schist.

Altered Silurian rocks of Highlands.

328. Brecciated Felspathic Conglomerate.

Lower Old Red Sandstone of Ochil range (?).

329. Trap-tuff.

Lower Old Red Sandstone of Ochils (?).

330. Quartz Rock Pebble.

From Lower Old Red Conglomerate of Ochils (?).

This stone at one time formed part of a coarse conglomerate. It was subsequently detached, and embedded in the boulder-clay, without being much worn on the way, though its surface retains some traces of striation.

331. Porphyrite.

From Ochil range (?).

332. Amygdaloidal Porphyrite.

From Ochil range (?).

333. Porphyrite.

From Ochil range (?).

334. Porphyrite (claystone).

From Ochil range (?).

335. Porphyrite.

From Ochil range (?).

336. Conglomerate.

The included pebbles consist largely of schist, quartz, and other Highland rocks. Large boulders of this rock were found at Craiglockhart, and were probably derived from some lower carboniferous conglomerate in the Fintry or Campsie district.

337. Cornstone, Lower Carboniferous.

Perhaps from Stirlingshire or the south-east flank of the Ochils.

338. Sandy Cement Stone.

From Lower Carboniferous series on south-east flanks of Ochils (?).

339. Limestone, with plant roots.

From the Mid-Calder or Queensferry limestone (?).

Window Case, 31.

340. Limestone, with *producti, encrinites,* etc.

Carboniferous limestone of Linlithgowshire or Stirlingshire (?).

341. Black-band Ironstone (mussel-band).

Linlithgowshire or Stirlingshire.

342. Ashy Limestone.

Resembles parts of the limestone of Kirkton, near Bathgate.

343. Ashy Sandstone.

Linlithgowshire (?).

344. Trap-tuff.

Linlithgowshire (?).

This specimen has quite the ordinary character of the Linlithgowshire tuffs. See the collection from that county.

345. Sandstone.

West of Edinburgh.

346. Dolerite.

This and the succeeding four specimens may have been derived from the numerous masses of trap which occur between Edinburgh and the Stirlingshire hills.

347. Porphyritic Melaphyre.

348. Dolerite.

349. Diorite.

From the Kirkliston and Queensferry district.

350. Melaphyre.

The next suite of specimens was obtained from the stratified clays of the brick-pits at Portobello. They are placed here to show the general character of the stones in these upper clays. The same evidence of a prevalent transport from west or north-west is found here as in the boulder-clay; but there are also traces of movement from other quarters, as shown by No. 358. The striæ on the stones are much less distinct than on those in the boulder-clay, and sometimes they are wholly absent. That these stratified clays were formed on the sea-floor is shown by the presence of *foraminifera* and *entomostraca* (Nos. 360, 361), and the occasional occurrence of shells of *Scrobicularia piperata* in their position of growth, while the proximity of land is indicated by the twigs and roots of oak (No. 359), beech, hazel, etc., which are sometimes found in considerable quantity.

351. Five **Stones,** from crystalline rocks of Highlands.

352. Black-band Ironstone (mussel-band).

353. Cannel Coal.

Linlithgowshire.

This and the foregoing specimen are well striated.

354. Limestone, with encrinites, etc.

Linlithgowshire.

355. Clay Ironstone Nodule.

356. Diorite.

Neighbourhood of South Queensferry.

Window Case, 31.

357. Melaphyre.

358. Fragment of Chalk.

This specimen exhibits abundant spicules of sponges when examined under the microscope.

359. Fragments of Oak.

Larger specimens, collected by the late Mr. Hugh Miller, are in another case in this room.

360. Foraminifera.

Brick-clay, Portobello.

361. Entomostraca.

Brick-clay, Portobello.

PEEBLESSHIRE.

The Lower Silurian greywackes and shales are cut in many places by various dykes or vertical walls of igneous rock, which usually coincide in direction with the strike of the strata, but occasionally break through the beds in a very irregular manner. (See Diagrams accompanying the specimens, Nos. 1, 2, and 3.) These dykes often occur in clusters, and along certain lines, and in places so numerous are they, and so closely associated, that it becomes impossible to separate them out upon a map. There are wide districts in the Silurian uplands of Peeblesshire, however, where no dykes have been met with. One of the best localities for the study of these dykes occurs at Priesthope Hill, in the neighbourhood of Innerleithen, on the Tweed. In this hill, and the neighbouring streams, abundant igneous veins and dykes intersect and traverse the nearly vertical Silurian strata. In lithological character, the rocks of these dykes and veins have a general resemblance, and are perfectly distinct, and easily distinguished from the trap-dykes which are usually found associated with carboniferous and later-formed strata.—(See Case 29.) They consist of varieties of felstone and micaceous porphyries. Hornblende is often plentifully present; and many of the rocks are highly silicated, and contain abundant globules of clear quartz. The base of these rocks consists usually of orthoclase, which frequently occurs in distinct crystals, scattered more or less abundantly through the felsitic base. The following specimens (Nos. 1–21) illustrate the general character of these rocks.

1. Felstone.

Collie Law, Eddleston Water.

2. Felstone.

Priesthope Burn, Innerleithen.

Contains a little mica.

3. Felstone.

Priesthope Burn, Innerleithen.

4. Felstone.

Priesthope Burn, Innerleithen.

Contains mica, and a little iron pyrites.

5. Felspar Porphyry.

Troon Hill, Innerleithen.

The felspar scattered through the felsitic base is orthoclase.

6. Hornblendic Porphyry.

Priesthope Burn, Innerleithen.

7. Micaceous Porphyry.

Priesthope Burn, Innerleithen.

8. Micaceous Porphyry.

Priesthope Burn, Innerleithen.

9. Quartziferous Porphyry.
Priesthope Burn, Innerleithen.

Grey felspathic rock, with mica and abundant globules of quartz.

10. Quartziferous Porphyry.
Priesthope Burn, Innerleithen.

Similar rock as preceding.

11. Micaceous Porphyry.
Priesthope Burn, Innerleithen.

12, 12.* Quartziferous Porphyry.
Priesthope Burn, Innerleithen.

Pale greyish felspathic rock, with black mica and free quartz. Specimens show junction with hardened greywacke.

13. Micaceous Porphyry.
Priesthope Burn, Innerleithen.

14. Hornblendic Porphyry.
Caerlee Hill, Innerleithen.

Window Case, 31.

15. Quartziferous Porphyry.
Pyat Hill, River Tweed, below Innerleithen.

Dark red felspathic rock, with mica and free quartz.

16. Micaceous Porphyry.
Manse, Innerleithen.

[See Diagram No. 2, accompanying specimen.]

17. Micaceous Porphyry.
Priesthope Burn, Innerleithen.

18. Hornblendic Porphyry.
Turf Knowe, Innerleithen.

19. Hornblendic Porphyry.
Priesthope Burn, Innerleithen.

20. Micaceous Porphyry.
Priesthope Burn, Innerleithen.

21. Minette.
Kirnie Law, Innerleithen.

Reddish felspathic rock with mica.

AYRSHIRE.

ALTERED ROCKS OF LOWER SILURIAN AGE.

The Lower Silurian strata in the south of Ayrshire exhibit considerable metamorphism,—the felspathic and calcareous greywackes, though of aqueous origin, having in many places assumed the aspect of igneous rocks. These appearances are well displayed along the sea-coast between Ballantrae and Lendalfoot, and upon the rocky slopes and in the stream courses of the neighbourhood. Passages from unaltered and distinctly granular greywacke into crystalline porphyritic and amygdaloidal rocks can be traced, the porphyritic and amygdaloidal rocks not being distinguishable from those which have had a true igneous origin. The conglomerates of the same district are often highly altered, the rounded stones being squeezed into irregular shapes, and the whole rock becoming brecciform, and weathering with a surface greatly resembling that of a coarse volcanic agglomerate. Rounded pebbles, however, can be picked out here and there, even in the most altered parts of the conglomerates (see Nos. 17 and 19). Limestone is frequently associated with the conglomerates of this district, and like the other rocks often exhibits considerable alteration, becoming crystalline, and

Window Case, 31. being abundantly veined with serpentine, steatite, and other magnesian silicates. Where the conglomerates have undergone the greatest degree of metamorphism, the limestones frequently disappear and are replaced by serpentine. The altered rocks of this district may be grouped into three classes—felspathic rocks, dioritic rocks, and serpentines. The felspathic rocks are by far the most abundant, and vary much in structure and aspect. The diorites and serpentines have a more definite character, and are often interbedded or closely associated. But the one class shades into the other, and no strongly marked line of division between them can be drawn upon a map. The metamorphic changes which have affected these Lower Silurian strata can hardly be exhibited in hand specimens, but must be studied in the field. The specimens which follow exhibit in a general way the character of the altered rocks.

[See Diagram No. 1 for general section across the metamorphic strata in the south of Ayrshire; also Sheet No. 7 of the Geological Survey Map of Scotland.]

1. **Greywacke** (unaltered rock).

South of Balcreuchan Port, near Ballantrae, Ayrshire.

[2–5. Specimens to illustrate the character of the altered crystalline rocks. They are of a very variable character, sometimes being close-grained, semi-crystalline; sometimes granular-crystalline; in other places distinctly crystalline, with large felspar crystals scattered throughout. The rocks occasionally contain a little hornblende, and thus become dioritic.]

2. **Altered Rock.**

Shore, Lendalfoot, Ayrshire.

Dark, fine-grained, crystalline, felspathic rock, sparingly porphyritic with felspar.

3. **Altered Rock.**

Shore, Lendalfoot, Ayrshire.

Has somewhat the same character as preceding (2).

4. **Altered Rock.**

Shore, Lendalfoot, Ayrshire.

Porphyritic felspathic rock.

5. **Altered Rock.**

Shore, Lendalfoot, Ayrshire.

Highly porphyritic felspathic rock.

[6–9. Various porphyritic felspathic rocks, to illustrate the character of the altered felspathic greywackes of the district.]

6. **Altered Rock.**

Chapman's Craig, Shore, near Lendalfoot, Ayrshire.

7. **Altered Rock.**

Knockgowan, near Ballantrae, Ayrshire.

8. **Altered Rock.**

Balcreuchan Port, north of Ballantrae, Ayrshire.

9. **Altered Rock.**

Near Knockdolian, Ayrshire.

10. **Amygdaloid** (metamorphic).

Port-Vad, Ballantrae, Ayrshire.

From small area of altered rock enclosed in greenish coloured greywacke; cavities filled with carbonate of lime.

11, 12. **Altered Greywacke.** *Window Case,* 32.

North-west end of Craighead Hill, near Girvan.

13. **Amygdaloid** (metamorphic greywacke).

Port-Vad, near Ballantrae, Ayrshire.

This specimen illustrates the character assumed by many of the altered rocks of the district. The amygdaloidal cavities are generally globular, and the kernels are seldom or never larger than sweet peas.

14. **Amygdaloid** (metamorphic greywacke).

Port-Vad, near Ballantrae, Ayrshire.

[15–19. ALTERED CONGLOMERATE. — In these conglomerates the stones are sometimes completely obliterated. Smoothed and rounded stones are not common; the whole rock appears to have been softened, and the stones to have lost their original rounded outlines. The rounded smooth-faced stones still observed are usually fragments of Lydian stones, and other hard fine-grained rocks. These altered conglomerates have frequently the appearance of volcanic agglomerates—they weather with a rough, almost scoriaceous surface, as is well seen in 15.]

15. Altered Conglomerate.

Bennane Head, Ballantrae, Ayrshire.

16. Altered Conglomerate.

Bennane Head, Ballantrae, Ayrshire.

Shows a vesicular surface on a rounded stone.

17. Altered Conglomerate.

Bennane Head, Ballantrae, Ayrshire.

Shows rounded stone in rough angular matrix.

18. Altered Conglomerate.

Knockdolian Hill, Ballantrae, Ayrshire.

19. **Rounded Stones** from Altered Conglomerate.

Bennane Head, near Ballantrae, Ayrshire.

20. 'Green Paste Rock.'

Window Case, 32.

Port-Vad, Ballantrae, Ayrshire.

Altered Greywacke. A rock of very variable aspect, generally of a greenish colour; sometimes distinctly granular, sometimes semi-crystalline; in other places crystalline, porphyritic and amygdaloidal.

[See Diagram No. 2, accompanying this specimen.]

21. Altered Conglomerate.

Knockgowan, Ballantrae, Ayrshire.

Highly altered portion of rock—crystalline and amygdaloidal.

22. Altered Rock.

Burnfoot, near Ballantrae, Ayrshire.

From portion of altered conglomerate. A fine-grained crystalline felspathic rock, becoming dioritic in places.

23. **Altered Rock** ('Green Paste Rock').

Balcreuchan Port, Ballantrae, Ayrshire.

Very serpentinous rock, of the same general character as 20.

24. Altered Conglomerate.

Mains Hill, Ballantrae, Ayrshire.

Dark crystalline rock, with much hornblende in distinct crystals. The 'stones' are best seen on weathered faces.

25. Altered Rock.

Balcreuchan Port, Ballantrae, Ayrshire.

Dark mottled red and green serpentinous felspathic rock; usually fine-grained, crystalline.

Window Case, 32.

26. Altered Rock.

Pierhead, Ballantrae.

Reddish crystalline felspathic rock; contains hornblende occasionally.

27. Altered Limestone (two Specimens).

Shore, Pinbain, Lendalfoot, Ayrshire.

From honeycombed mass of baked limestone in contorted and shattered and altered shales.

28. Calcareous Greywacke, or Impure Limestone.

Bennane Head, Ballantrae, Ayrshire.

This rock weathers like a breccia, with a rough, almost scoriaceous, surface.

[29, 30. ALTERED ROCKS. — These specimens illustrate the character of the metamorphic rocks which have assumed a dioritic aspect. The hornblende is scattered through the matrix in minute points.]

29. Fine-grained Diorite.

Near Craig Hill, Colmonell, Ayrshire.

30. Fine-grained Diorite.

Near Craig Hill, Colmonell, Ayrshire.

This rock is associated with green serpentine.

[31-36. ALTERED ROCKS. — These specimens exhibit the character of the metamorphic rocks which contain diallage, hypersthene, etc. The felspar of these masses being supersilicated and the pyroxenic minerals much interlaced, the rocks are rendered excessively hard and tough.]

31. Altered Rock.

Shore, Pinbain, Lendalfoot, Ayrshire.

32. Altered Rock.

Shore, Pinbain, Lendalfoot, Ayrshire.

33. Altered Rock.

Between Byne Hill and Fell Hill, south of Girvan, Ayrshire.

34. Altered Rock.

Sallachan Hill, near Ballantrae, Ayrshire.

35. Altered Rock (hyperite).

Shore, Lendalfoot, Ayrshire.

36. Altered Rock (hyperite).

Breaker Hill, near Colmonell, Ayrshire.

37. Diallage, from altered rocks.

Shore, Lendalfoot, Ayrshire.

38. Diallage.

Shore, Lendalfoot, Ayrshire.

From junction of serpentine with hyperite.

39. Syenite.

Balnowlart Knowes, near Ballantrae, Ayrshire.

40. Syenite.

Byne Hill, near Girvan, Ayrshire.

41, 42. Serpentine and **Altered Rock.**

Shore, Lendalfoot, Ayrshire.

Shows junction of serpentine and altered rock.

43. Altered Rock.

Near Knockdaw Hill, Colmonell, Ayrshire.

Serpentine with felspar; rock becoming hornblendic; to illustrate passage of serpentine into diorite.

Window Case, 32.

[44–52.—Various serpentines, all of which are probably altered silurian rocks. Many of these serpentines are associated with limestones, or occur on the same horizon with limestones. They are also closely allied to the dioritic rocks of this region. See 29 and 43.]

44. Serpentine.

Shore, near Lendalfoot, Ayrshire.

45. Serpentine.

Sallachan Hill, near Ballantrae, Ayrshire.

Shows rudely schistose character.

46. Serpentine with **Bronzite.**

Balhamie Hill, Colmonell, Ayrshire.

47. Serpentine with **Bronzite.**

Near Lendalfoot, Ayrshire.

48, 49. Serpentine.

East end of Byne Hill, Girvan, Ayrshire.

50. Serpentine with **Bronzite.**

Byne Hill Burn, Girvan, Ayrshire.

51. Red Serpentine.

Whilk, near Lendalfoot, Ayrshire.

52. Red Serpentine, mottled green.

Burnfoot, near Lendalfoot, Ayrshire.

53. Serpentinous Altered Rock.

Craighead, near Girvan, Ayrshire.

54. Lydian Stone.

Knockgowan, near Ballantrae, Ayrshire.

55, 56. Altered Rock.

Lendalfoot, Ayrshire.

To show junction of crystalline porphyritic felspathic altered rock with serpentine.

57. Pectolite.

Shore, Lendalfoot, Ayrshire.

From veins in altered felspathic rocks.

DYKES CUTTING SILURIAN ROCKS.

The Lower Silurian strata of the south of Ayrshire are cut by dykes and veins of igneous rock, which have a general resemblance to the similar intrusive rocks traversing the Silurian strata of Peeblesshire. (See Case 31, Nos. 1–21, p. 48.) Here and there these dykes pierce the altered rocks (Nos. 1–56) in such a way as to lead to the inference that they are of subsequent date to the metamorphism of the district. They are not numerous.

58. Diorite.

Glen Burn, Glen App, Ayrshire.

Cutting Lower Silurian greywacke and shale.

59. Felstone, approaching Hornstone in aspect.

Glen Burn, Glen App, Ayrshire.

Cutting Lower Silurian greywacke and shale.

Window Case, 32.

60. Felstone.

Glen Burn, Glen App, Ayrshire.

Cutting Lower Silurian greywacke and shale.

61. Minette or **Micaceous Porphyry.**

Glen Burn, Glen App, Ayrshire.

Cutting Lower Silurian greywacke and shale.

62. Minette or **Micaceous Porphyry.**

Glen Burn, Glen App, Ayrshire.

Cutting Lower Silurian greywacke and shale.

Window Case, 33.

OLD RED SANDSTONE.

LOWER SERIES.

The strata from which the following specimens (65–115) are taken, occur in the neighbourhood of Dalmellington, the Water of Girvan above Straiton, and in the district immediately to the south of Loudoun Hill (River Irvine). They consist of a great series of sandstones, flagstones, and conglomerates, with interbedded rocks of volcanic origin. Near Loudoun Hill, and in the district of the Water of Girvan, the strata have undergone some degree of metamorphism, the felspathic sandstones having been converted into granite, minette, and other crystalline rocks. *Cephalaspis Lyellii* has been obtained from unaltered beds of flagstone in the district of Loudoun Hill.

63. Fine Pebbly Quartzose Conglomerate.

Upper Reservoir, Muirkirk.

64. Quartz Pebble, from Conglomerate.

Rob's Hill, near Douglas, Lanarkshire.

ALTERED ROCKS OF LOWER OLD RED SANDSTONE SERIES.

District of Water of Girvan, near Straiton.

65–77. These specimens illustrate the character of certain metamorphosed rocks of Lower Old Red Sandstone age, which occur in the neighbourhood of Knockdon, on the Water of Girvan, about five miles above the village of Straiton. The unaltered strata of that district consist of red and grey felspathic sandstones, and occasional conglomerates, with which are associated certain igneous rocks (porphyrites, etc.). 65–74 exhibit the general character of the altered rocks of aqueous origin. 75–77 show the nature of the associated igneous rocks, which, like the aqueous rocks, have also undergone some degree of metamorphism since the time of their formation. The general character of the metamorphism of this district is somewhat similar to that which has affected another area of Lower Old Red Sandstone in Ayrshire (see p. 55).

65, 66, 67. Altered Conglomerate.

Knockdon Farm, Water of Girvan.

68. Felspathic Conglomerate.

Craigens, near Straiton.

Window Case, 33.

[69–71. ALTERED CONGLOMERATE.—These specimens show the aspect presented by the conglomerates in their more highly altered portions.]

69. Altered Conglomerate.

Girvan Water, Foreburn.

Pinkish-grey felspathic rock with zeolitic mineral; the pebbles obliterated by metamorphism.

70. Altered Conglomerate.

Foreburn, Water of Girvan.

Same rock as 69.

71. Altered Conglomerate.

Knockdon, Water of Girvan.

Same general character as 69, 70, but finer grained.

72. Altered Rock.

Foreburn, Water of Girvan.

Illustrates the character presented by some of the metamorphosed rocks of aqueous origin.

73. Altered Rock.

Foreburn, Water of Girvan.

Same as 72.

74. Altered Rock.

Foreburn, Water of Girvan.

Highly metamorphosed aqueous rock; quite crystalline, and containing abundance of a dark zeolite.

75. Porphyrite.

Tairlaw Ring, Water of Girvan.

This rock is of igneous origin, but has undergone some degree of alteration.

76. Porphyrite.

Tairlaw Ring, Girvan Water.

From the same bed as the preceding specimen (75).

77. Amygdaloidal Porphyrite.

Tairlaw Ring, Girvan Water.

78. Intrusive Porphyrite.

Knockdon, Water of Girvan.

From an intrusive mass cutting altered conglomerate. The rock contains much serpentinous matter. Compare with 69, 70, and 71 (metamorphic rocks), which it closely resembles.

79. Intrusive Porphyrite.

Knockdon, Water of Girvan.

Same as 78.

District of Lanfine Moor.

80–99. The following series of specimens illustrates the character of certain metamorphic rocks of Old Red Sandstone age. The district where these rocks occur lies between Loudoun Hill, on the River Irvine, and the village of Sorn, on the River Ayr. The unaltered strata of this district consist of a series of flagstones, sandstones, grits, and conglomerates. As the flagstones have yielded specimens of *Cephalaspis Lyellii*, the strata must be referred to the Lower Old Red Sandstone formation. All the beds are highly felspathic, and appear to be made up out of the triturated remains of pre-existing felspathic rocks. They vary in texture from fine close-grained to coarse gritty admixtures of grey and pink felspar (oligoclase and orthoclase), with quartz in variable proportions. Nests or galls of fine mudstone or clay occur throughout, and in some places are so abundant as to impart a spotted or blotchy aspect to the rock. The metamorphism which has affected these strata first shows itself in a slight hardening of the rock; and this induration gradually increases, until the sandstones lose their dull granular texture and rough

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irregular fracture, and begin to assume a glistening semi-crystalline aspect, and to break with a splintery and conchoidal fracture. From this semi-crystalline condition every gradation may be traced, until we reach distinctly crystalline rocks, like minette and granite. Those portions of the original unaltered strata, which are either quartzless, or in which quartz is present only in meagre proportion, are metamorphosed in places into minette (a granular-crystalline admixture of orthoclase and mica), and such granites as contain quartz sparingly; while the more highly quartzose sandstones have been changed into red and grey granites of the common type—namely, granular admixtures of felspar, quartz, and mica.

The altered rocks of this region, which are intermediate in character between indurated semi-crystalline sandstone on the one hand, and granite on the other, are not well illustrated by museum specimens. It is often difficult to give them a definite lithological designation, for the appearances they present are inconstant. Sometimes they appear as finely crystalline felstone, in which points of black mica frequently present themselves. Again the mica will show itself in large flakes, and cause the rock to assume a distinctly porphyritic character, and with the mica a few scattered points of quartz will occasionally be associated. In other places mica is absent and quartz present. Hornblende also occurs porphyritically in some of these rocks, and fine points of iron pyrites appear in almost all. None of these lithological characters, however, is long constant, but the one variety of rock quickly passes into the other. The nests of clay which are met with in the unaltered strata become baked into porcellanite in some places, and in the granites are perhaps represented by certain dark-grey or black crystalline 'galls,' in which mica occurs abundantly.

When it is considered that the mineralogical composition of the unaltered strata and the crystalline rocks is the same, and that a distinct passage can be traced from granular and slightly altered felspathic sandstones through various kinds of crystalline rock (the main constituent of which is felspar with quartz and mica, more or less abundant in places), into such rocks as minette and granite, it will hardly be doubted that the felspathic sandstones have actually been changed by metamorphic action into these igneous-like masses. And this conclusion is still further borne out when we come to study the relation of the crystalline rocks to the surrounding unaltered sandstones. These last are not broken through and violently displaced; there is no appearance of confusion in the bedding as we approach the metamorphic centres. On the contrary, the dip and strike of the strata continue unchanged and perfectly distinct until the rocks begin to assume a baked and semi-crystalline texture, and then the bedding gradually becomes obscure, and at last vanishes altogether. But when we have traversed the metamorphic area and reached the unaltered strata on the further side, we find the sandstones erelong appearing with exactly the same dip and strike, and giving no evidence of disruption by great masses of igneous rock. The impartial observer cannot but conclude that the felspathic sandstones were once continuous across the area now covered by crystalline rocks, and the belief is forced upon him that these crystalline rocks have not been erupted from below, but are in truth only the felspathic sandstones under a different form. The sandstones have been simply metamorphosed into crystalline rocks—they have changed their texture while retaining their mineralogical composition.

Numerous dykes of felstone, micaceous porphyries, and other allied rocks, occur in this district, and are probably connected in some way with the centres of metamorphism, for they appear in greatest numbers as we approach the region of crystalline rocks. The same phenomena have been observed in other localities. [See Nos. 198-207, and Sketch-section No. 3 accompanying the specimens.]

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[80–85. Various specimens of felspathic sandstone, to show the general character of the Old Red Sandstone in the metamorphic region above referred to.]

80. **Sandstone.**

Tulloch Burn, near Darvel, Ayrshire.

A granular admixture of felspathic matter and quartz, with fine points of iron pyrites scattered throughout.

81. **Sandstone.**

Changue Burn, near Darvel, Ayrshire.

A granular admixture of pink and grey felspar with quartz, with occasional galls or nests of fine clay; the rock somewhat hardened and altered.

82. **Sandstone.**

Tulloch Burn, near Darvel, Ayrshire.

A rock of much the same character as the preceding sandstone (81).

83. **Sandstone** (altered).

Ladystone Linn, near Darvel, Ayrshire.

Same character as the sandstones 81, 82, but much hardened and altered, and approaching the crystalline condition.

84. **Sandstone** (altered).

Changue Burn, Darvel, Ayrshire.

Hardened and altered from contact with dyke of igneous rock; to compare with 81, 82, and 83, which do not owe their hardened and altered condition to the same cause, but assumed their present aspect during the general metamorphism of the district.

85. **Sandstone** (altered).

Horn Burn, near Loudoun Hill, Ayrshire.

Much hardened and altered, and approaching a crystalline texture. Granular admixture of felspathic matter and quartz, with occasional nests of clay.

86. **Altered Sandstone.**

Ladystone Linn, Tulloch Burn, near Darvel, Ayrshire.

Shows passage of semi-crystalline into crystalline rock; small points of iron pyrites scattered throughout.

87. Junction of **Altered Rock** with **Intruded Rock.**

Tulloch Burn, near Loudoun Hill, Ayrshire.

To compare with 86, 89, and 90, in which a gradual passage from the semi-crystalline into the crystalline condition may be noted. In this specimen, the junction of the hardened semi-crystalline altered rock with the fine-grained compact porphyritic igneous rock is well marked and distinct.

88. **Altered Rock** (felspathic sandstone).

Ladystone Linn, Tulloch Burn, near Darvel, Ayrshire.

Highly altered crystalline felspathic rock, with iron pyrites—same as the crystalline rock in 86.

89. **Altered Rock** (felspathic sandstone).

Ladystone Linn, Tulloch Burn, near Darvel, Ayrshire.

Shows passage from semi-crystalline into crystalline rock.

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90. Altered Rock (felspathic sandstone).

Tulloch Burn, near Darvel, Ayrshire.

Shows passage from hardened semi-crystalline altered rock into crystalline rock.

91. Altered Rock.

Tulloch Burn, near Darvel, Ayrshire.

Dark greenish crystalline felspathic rock, with a few small points of mica.

92. Altered Rock.

Tulloch Burn, near Darvel, Ayrshire.

Dark greyish-blue crystalline felspathic rock, with black mica.

[93–99. GRANITES.—These specimens exhibit the ultimate stage of metamorphism assumed by the felspathic sandstones of the Lower Old Red Sandstone series in this district. The granites differ from each other chiefly in the relative proportion of the quartz.

93. Granite (metamorphic).

Watstone Hill, near Loudoun Hill, Ayrshire.

Ternary compound of felspar, quartz, and black mica.

94. Granite (metamorphic).

Watstone Hill, near Loudoun Hill, Ayrshire.

95. Granite (metamorphic).

Watstone Hill, near Loudoun Hill, Ayrshire.

96. Granite (metamorphic).

Watstone Hill, near Loudoun Hill, Ayrshire.

97. Granite (metamorphic).

Watstone Hill, near Loudoun Hill, Ayrshire.

Quartz is very sparingly present in this rock.

98. Granite (metamorphic).

Dubs Burn, near Darvel, Ayrshire.

Shows small 'nest.'

99. Granite (metamorphic).

Dubs Burn, near Darvel.

The felspathic sandstones and metamorphic rocks illustrated by the preceding specimens are overlaid conformably by a series of porphyrites, with interbedded ashy sandstones, grits, and conglomerates. The general character of these rocks is shown by the succeeding specimens (100–108).—[See Sketch-sections (Nos. 3 and 4) accompanying specimens.]

100. Felspathic Grit or **Sandstone.**

Wilson's Hill, near Darvel.

101. Felspathic Grit.

Lanfine Woods, Newmilns.

102. Felspathic Grit.

Lanfine Woods, Newmilns.

[103–105. AMYGDALOIDAL PORPHYRITES.—These rocks in this district do not exhibit much variety. They are frequently very coarsely amygdaloidal, the cavities being filled with kernels of quartz, chalcedony, calcite, and agates, some of which are as large as one's fist. This locality (Galston and Newmilns) has long been noted for these 'Scotch pebbles'—very large specimens of which are often turned up by the plough in the loose trappean soil. These last appear rather to have been formed as veins in irregular crevices in the trap than in the usual amygdaloidal cavities.

103. Amygdaloidal Porphyrite.

Downie's Burn, Lanfine.

104. Amygdaloidal Porphyrite.

Lanfine Woods, Newmilns.

105. Amygdaloidal Porphyrite.

Lanfine Woods, Ayrshire.

106. Amygdaloidal Porphyrite.

Changue, Darvel.

107. Amygdaloidal Porphyrite.

Downie's Burn, Darvel.

108. Amygdaloidal Porphyrite.

Tulloch Burn, Darvel.

[109-115. Various porphyrites to illustrate the character of the Lower Old Red Sandstone igneous rocks in the neighbourhood of Dalmellington.]

109. Amygdaloidal Porphyrite.

Shear Hill, Dalmellington.

110. Porphyrite. *Window Case, 33.*

Maratz Hill, near Dalmellington.

Rock sparingly amygdaloidal.

111. Porphyrite. *Window Case, 34.*

White Leys, Widow's Loch, near Dalmellington.

Rock sparingly amygdaloidal.

112. Porphyrite.

White Leys, Widow's Loch, near Dalmellington.

Same as 111.

113. Amygdaloidal Porphyrite.

White Leys, Widow's Loch, near Dalmellington.

114. Amygdaloidal Porphyrite.

Maratz Hill, near Dalmellington.

115. Amygdaloidal Porphyrite.

Maratz Hill, near Dalmellington.

MIDDLE (?) OLD RED SANDSTONE SERIES.

The following specimens (116 to 182) are illustrative of that great series of red and greenish sandstones and conglomerates, with associated beds of volcanic rocks, which rests unconformably on the Lower Old Red Sandstone group in the south of Ayrshire, and is now provisionally described as a Middle group.—(See Diagrams Nos. 5, 6, and 7, which show the relation of the Middle to the Lower Old Red Sandstone series.) The Middle Old Red Sandstone series occurs in the neighbourhood of Girvan, Kirkoswald, Maybole, Straiton, and Dalmellington. Some of the red micaceous sandstones at the top of the series have yielded *Pterichthys major*.

116. Conglomerate.

Dunure, seven miles south of Ayr.

This specimen is taken from a bed interstratified among the igneous rocks. It shows a number of well-rounded pebbles of different melaphyres, porphyrites, etc., embedded in a paste of the same materials in a finely comminuted state.

117. Ashy Sandstone.

Dunure, Ayr.

A fine aggregate of small fragments of different volcanic rocks embedded in a dull dirty-green felspathic base.

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118. Ashy Sandstone.

Dunure, Ayr.

Well-stratified felspathic rock, one of the layers being a fine ashy aggregate of small fragments of different volcanic rocks.

119. Ashy Grit.

Auldcraigoch Hill, Dalmellington.

Dark felspathic rock, consisting of finely comminuted fragments of volcanic rocks embedded in a dark felspathic base.

120. Porphyrite.

High Newlands, Dailly.

121. Porphyrite.

Auchenroy Hill, Dalmellington.

Full of small crystals of rubellan.

122. Porphyrite.

Kildown Hill, Maybole.

123. Porphyrite.

Kildown Hill, Maybole.

124. Porphyrite.

Drumbrae Quarry, Maybole.

125. Porphyrite.

Drumbrae Quarry, Maybole.

126. Porphyrite.

Hollowshean, Kirkoswald.

127. Porphyrite.

North-east end of Craigfin Hill, Maybole.

128. Porphyrite.

Quarter of a mile west of West Craigfin, Maybole.

129. Porphyrite.

North end of Craigfin Hill, Maybole.

130. Porphyrite.

Shore at Dunure.

Dark compact base, with numerous scattered crystals of oligoclase.

131. Porphyrite.

Cliffs to south of Heads of Ayr.

132. Porphyrite.

Cliffs to south of Heads of Ayr.

Dark base, with oligoclase crystals scattered through it.

133. Porphyrite.

Turnberry Castle.

134. Porphyrite.

Turnberry Point.

135. Porphyrite.

Redburn, Grimmet, Dalmellington.

136. Porphyrite.

Auchenroy Hill, Dalmellington.

137. Porphyrite.

Trostan Hill, near Straiton.

138. Porphyrite.

Near Glenhead, Dalmellington.

139. Porphyrite.

Auchenroy Hill, near Glenhead, Dalmellington.

140. Porphyrite.

Cliffs south of Heads of Ayr.

Sparingly amygdaloidal.

141. Porphyrite.

Darsalloch Hill, Dalmellington.

142. Porphyrite.

Auchenroy Hill, near Glenhead, Dalmellington.

143. Porphyrite.

Quarter of a mile west of West Craigfin, two and a half miles south of Maybole.

144. Porphyrite.

Auldcraigoch Hill, Dalmellington.

145. Porphyrite.

Turnberry Point.

Porphyritic, with abundant oligoclase crystals, and minute grains and crystals of a decomposing ferruginous mineral.

146. Porphyrite.

Largs Hill, Straiton.

Porphyritic, with oligoclase.

147. Porphyrite.

Auchenroy Hill, Glenhead, Dalmellington.

Porphyritic, with oligoclase, and sparingly amygdaloidal.

148. Porphyrite.

Craigens, near Baing, four and a half miles south-west of Dalmellington.

149. Porphyrite.

Auchenroy Hill, Dalmellington.

Contains much serpentinous matter.

150. Porphyrite.

Turnberry Point.

151. Porphyrite.

Auchenroy Hill, Dalmellington.

Amygdaloidal in part.

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152. Porphyrite.

Auchenroy Hill, near Grimmet, Dalmellington.

Amygdaloidal in part.

153. Porphyrite.

Knockdow Hill, near Baing, by Straiton.

Finely amygdaloidal.

154. Porphyrite.

Carthreavy Knowes, Dalmellington.

Finely amygdaloidal rock.

155. Porphyrite.

Trostan Hill, near Straiton.

Somewhat amygdaloidal.

156. Porphyrite.

Mulrue, near Dunure.

Pseudo-slag-like surface, due to irregular weathering of the rock.

157. Amygdaloidal Porphyrite.

Largs Hill, near Straiton.

Abundant minute amygdaloidal cavities.

158. Amygdaloidal Porphyrite.

Near Glenhead, Dalmellington.

159. Amygdaloidal Porphyrite.

Largs Hill, near Straiton.

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160. Amygdaloidal Porphyrite.

Largs Hill, near Straiton.

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161. Amygdaloidal Porphyrite.

Cronberry, Auldcraigoch Hill, Dalmellington.

162. Amygdaloidal Porphyrite.

Auldcraigoch Hill, Dalmellington.

163. Amygdaloidal Porphyrite.

Kilachie Glen, Straiton.

164. Amygdaloidal Porphyrite.

Grimmet, Auchenroy Hill, Dalmellington.

165. Amygdaloidal Porphyrite.

Auchenroy Hill, near Glenhead, Dalmellington.

166. Amygdaloidal Porphyrite.

Mulrue, near Dunure.

In this specimen, as in Nos. 167 and 168, the amygdaloidal cavities are flattened and elongated in the direction of motion of the rock when it flowed out in a melted state.

167. Amygdaloidal Porphyrite.

Mulrue, Dunure.

168. Amygdaloidal Porphyrite.

Howmuir Quarry, Maybole.

The elongation of the amygdaloidal cavities is well shown in this specimen.

169. Amygdaloidal Porphyrite.

Cliffs, south of Heads of Ayr.

Cavities lined with green earth, and filled with calcspar, quartz, etc.

170. Amygdaloidal Porphyrite.

Cliffs, south of Heads of Ayr.

Cavities filled with calcspar and lined with green earth; a few large crystals of oligoclase scattered through the base.

171. Amygdaloidal Porphyrite.

Turnberry Point.

Cavities filled with calcspar, green earth, agates, etc.

172. Amygdaloidal Porphyrite.

Turnberry Point.

173. Amygdaloidal Porphyrite.

Turnberry Point.

174. Amygdaloidal Porphyrite.

Cliffs, south of Heads of Ayr.

175, 176. Hardened Sandstone in Slaggy Porphyrite.

Trostan Hill, near Straiton.

These specimens are taken from the bottom of a bed of porphyrite. The under surfaces of the porphyrites of the Middle Old Red Sandstone series frequently show confused interlacings and irregular veins of sandstone and mudstone. From the highly hardened and altered appearance of these interlacing veins and threads in the bottom portions of the porphyrites, it would seem as if the old lava currents had been poured out over the floor of a sea where sand and mud were being accumulated, some of which was caught up and rolled into the heated mass as it crept along. Such veins of sandstone are to be distinguished from the somewhat similar veins traversing the upper portions of the porphyrites. These last seem to be due to the washing in of sand into cracks in the old lava beds before the latter were covered by any other rock. Though these veins are vertical, or irregularly branching, the sandstone filling them is found to be stratified horizontally, or in conformity with the bedding of the porphyrite.

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177. Amygdaloidal Porphyrite and Sandstone.

Turnberry Point.

Showing junction of the lower surface of a porphyrite bed with the upper surface of an underlying bed of sandstone.

178. Slag-like Porphyrite.

Auchenroy Hill, Dalmellington.

This specimen shows the manner in which the surface of the old lava broke up into scoriæ, in the same way as modern lavas do when cooling.

179. Slag-like Porphyrite.

Mulrue, near Dunure.

In this specimen the amygdaloidal kernels have been weathered out, so as to restore the former scoriaceous aspect of the rock. The cavities are all pulled out in one direction, which indicates the line of movement of the lava before it cooled.—(See Nos. 166 and 168.)

180. Amygdaloidal Porphyrite.

Largs Hill, Straiton.

Amygdaloidal kernels dissolved out on weathered surfaces.

181. Porphyrite-tuff.

Ladycross Well, Maybole.

From some beds of fine-grained tuff, intercalated in the Red Sandstone series in the neighbourhood of Maybole. This rock seems to be derived from the detritus of different porphyrites, mingled with ordinary sandy sediment.

182. Porphyrite-tuff.

Mochrum Hill, Maybole.

From another group of ashy beds in the Old Red Sandstone series. This specimen shows several alternations of angular, gravelly tuff, evidently the product of volcanic eruptions, with fine sandy sediment.

IGNEOUS ROCKS INTRUDED IN THE OLD RED SANDSTONE SERIES.

In the southern parts of Ayrshire, the Lower and Middle Old Red Sandstone series are pierced by masses and dykes of intrusive felspathic rocks, usually flesh or pink coloured, and often quartziferous. These masses are possibly connected in some cases, if not in all, with the eruption of the porphyrites, etc., of the middle division of the formation. In the metamorphic district lying between Loudoun Hill and the River Ayr, near Sorn (see Nos. 80–99), the felstone dykes appear to be connected in some way with the metamorphism of that district. 183–195 are illustrative of the intrusive masses ; 198–207 of the dykes.

183. Micaceous Porphyritic Felstone.

Tairlaw Burn, by Straiton.

A flesh-coloured felsitic base, with scattered crystals of orthoclase and biotite.

184. Micaceous Porphyritic Felstone.

Shear Hill, Dalmellington.

A compact felsitic base, with crystals of orthoclase and hexagonal plates of biotite.

185. Micaceous Porphyritic Felstone.

Knockdon Craig.

Orthoclase and biotite scattered through a felsitic base.

186. Micaceous Porphyritic Felstone.

Carwaar Hill, Dalmellington.

Same character as preceding specimens, 183–185.—[See Diagram No. 3.]

187. Micaceous Porphyritic Felstone.

Wee Berbeth Loch, Dalmellington.

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188. Porphyritic Felstone.

Glessel Burn, Dalmellington.

189. Porphyritic Felstone.

Wee Hill of Glenmount, Dalmellington.

190. Felstone.

Grimmet Hill, Dalmellington.

Pale pinkish-grey felspathic rock, with a few scattered crystals of orthoclase decomposing.

191. Quartziferous Felstone.

Quarry, near Greenside, Muirkirk.

[192–197. These specimens illustrate the peculiar brecciform aspect which many of the intrusive felstones exhibit. This brecciform appearance is best seen on the weathered surfaces of the rocks.]

192. Brecciform Felstone.

Wee Berbeth Loch, Dalmellington.

This specimen shows a freshly broken surface ; a base of finely comminuted felsitic matter, with small irregular shaped fragments of a dark flesh-coloured felstone scattered throughout. The felstone is porphyritic with orthoclase and sparingly with biotite. The brecciform character is comparable to the scoriaceous aspect presented by some of the porphyrites of Old Red Sandstone age (see No. 178), and appears to be due to the cooling of some portions of the mass, and the subsequent fracturing of these during the forcible intrusion of the great bulk of the melted rock.

193. Brecciform Felstone.

Tairlaw Ring, Girvan Water.

Weathered surface of rock, showing the peculiar brecciform appearance described above (192).

194. Brecciform Felstone.

Tairlaw Ring, Girvan Water.

Fresh fractured surface of No. 193. Rock has the same composition as 192, but is less comminuted or broken, the felsitic fragments appearing as if set in a finely crystalline or compact base of felsitic matter.

195. Brecciform Felstone.

Tairlaw Ring, Girvan Water.

Another specimen from the same mass as 193 and 194.

196, 197. Brecciform Felstone.

Glenachie, Girvan Water.

These two specimens are from the same mass. The igneous rocks in this neighbourhood have undergone some degree of metamorphism since the time of their formation, and it is sometimes difficult to say which of them are intrusive and which have been erupted at the surface like modern lavas. The mass from which these specimens are taken may have flowed at the surface, like the unaltered porphyrites of the same region (Nos. 109 to 115), but the specimens are placed here for the sake of comparison with 192–195, which they closely resemble. It is only in the field that the interbedded character of this felstone suggests itself. It is probably of Lower Old Red Sandstone age.

198–207. These rocks occur generally in the form of dykes or veins, but occasionally in large masses. The dykes do not traverse the strata with the same regularity which characterizes the doleritic dykes of tertiary age (Case 44). They are frequently branching and interlacing, sometimes running along the strike of the strata, sometimes cutting across the beds at all angles. They are comparable with the dykes which traverse the Lower Silurian rocks of Peeblesshire.—(See Nos. 1–21, Case 31.)

Window Case, 35.

198. Porphyrite.

Logan Burn, Darvel.

From a dyke cutting Lower Old Red Sandstone rocks.

199. Porphyritic Felstone.

Glenout Burn, Darvel.

From a dyke cutting Lower Old Red Sandstone rocks. Flesh-coloured felsitic base, with scattered crystals of orthoclase, and a decomposing mineral, perhaps mica (biotite).

200. Porphyrite.

Logan Burn, Darvel.

From a dyke cutting Lower Old Red Sandstone strata.

201. Porphyrite.

Pennel Burn, Whitehaugh Water.

From a dyke cutting Lower Old Red Sandstone strata. 200 and 201 have much the character of some of the porphyrites erupted as lavas during the age of the Carboniferous Limestone.

202. Quartziferous Felstone.

Nether Priesthills, Muirkirk.

Globules of clear quartz, scattered through a grey fine-grained felsitic base—the decomposing mineral probably a mica.

203. Porphyrite.

Glenout Burn, Darvel.

From a dyke cutting Lower Old Red Sandstone strata. A dark felsitic base, with crystals of orthoclase scattered through it.

204. Felstone.

Changue Burn, Darvel.

From a dyke cutting Lower Old Red Sandstone strata.

205. Felstone.

Pennel Burn, Whitehaugh Water.

From a dyke cutting Lower Old Red Sandstone strata.

206. Felstone.

Pennel Burn, Whitehaugh Water.

From a dyke cutting Lower Old Red Sandstone strata.

207. Felstone.

Sornfalla Quarry, Tinto, Lanarkshire.

Compact base of felsitic matter, with scattered crystals of dark mica. A hard supersilicated rock.

208. Hæmatite.

Pennel Burn, Whitehaugh Burn.

From vein in Lower Old Red Sandstone rocks.

209. Barytes or **Heavy Spar.**

Gaswater, near Shawfield.

This specimen is taken from a vein in a line of fault which intersects the Lower Old Red Sandstone and Calciferous Sandstone series.

CARBONIFEROUS.

Window Case, 36.

The Carboniferous strata of Ayrshire are divisible into three groups, which, in descending series, are as follows:—

Coal Measures, consisting of—

b. Red sandstones, fireclays, and marls, with carboniferous plants, and

Window Case, 36.

a seam of limestone containing *Spirorbis carbonarius*. No workable coal-seams in this group.

a. A thick group of white and grey sandstones, dark shales, fireclays, ironstones, and coal-seams.

Carboniferous Limestone Series. A suite of sandstones, shales, and limestones, with seams of coal.

Calciferous Sandstone Series, consisting of—

b. A variable group of white sandstones, cement-stones, and marls, below which lies

a. A group of red sandstones, marls, and cornstones.

CALCIFEROUS SANDSTONE SERIES.

210. Dolerite-tuff.

Heads of Ayr.

This rock forms a bold sea-cliff, and is associated with the Calciferous Sandstone series. The present specimen consists of a dull earthy base, containing a gravelly assortment of subangular and rounded fragments of altered dolerite, etc.

211. Dolerite-tuff.

Heads of Ayr.

212. Basalt, from dyke in tuff.

Heads of Ayr.

The tuff is traversed by a number of small basalt dykes, which probably belong to the same period of volcanic activity.

213. Basalt, from dyke in tuff.

Heads of Ayr.

214. Dolerite-tuff.

Greenan Castle, Ayr.

This rock resembles that of the Heads of Ayr, with which, indeed, it is probably contemporaneous. It is in one part well-stratified; but on the beach it is in places quite amorphous, and may there be seen abruptly breaking through the sandstones and shales.

215. Fragment of Wood, from tuff of Greenan Castle.

216, 217. Two **Fragments of Calcareous Conglomerate,** embedded in the tuff of Greenan Castle.

218. Fragment of Limestone. One of the stones in the tuff of Greenan Castle.

219. Ashy Shale.

Greenan Castle.

This bed overlies the tuff No. 214, and shows how, while the volcanic forces were dying out here, the fine felspathic dust was mingled with the ordinary sediment of the sea-bottom.

220. Limestone, in Calciferous Sandstone series.

Shore, two and a half miles south-west of Ayr.

221. Concretionary Limestone.

Whitehaugh Water, Garpel.

222. Sandy Limestone.

Shore, two and a half miles south-west of Ayr.

Contains *myalina*, cyprids, plants, fish-scales, etc.

223. Cement-stone.

Shore, two and a half miles south-west of Ayr.

[See Sketch-section (No. 8) accompanying specimens for the relation of the Calciferous Sandstone series to the overlying Carboniferous Limestone series, and the underlying Old Red Sandstone.]

CARBONIFEROUS LIMESTONE SERIES OF AYR AND RENFREW SHIRES.

Window Case, 36.

The Carboniferous Limestone strata of the north part of Ayrshire and the south part of Renfrewshire, contains as its lowest member a great series of volcanic rocks. These rocks form the uplands of Renfrewshire, and stretch across the boundaries of that county into Ayrshire and Lanarkshire. The area from which the succeeding specimens have been selected, extends in a north-west direction from the valley of the Avon Water at Strathavon, to the high grounds east of Beith and Lochwinnoch. The following localities mark the northern limits of the trappean region:—Gleniffer Braes, south of Paisley; Cathkin Hills, south of Rutherglen; Neilston; Balgray Reservoirs; Busby; Eaglesham; Cleuchearn, and Chapelton. The southern boundary (which is a very sinuous one) is roughly indicated by the following places:—Giffen Castle; Bloak Mill and Gameshill, near Dunlop; Glenouther Muir; Cutstraw, near Stewarton; Fenwick; Cameron's Moss; Newmilns; Darvel; and Loudoun Hill. The rocks of this district consist of a great variety of bedded anamesites, basalts, melaphyres, and porphyrites, interstratified in places with bands of fine tuff and coarse volcanic agglomerate, and with occasional sandstones, shales, and thin impure limestones.—(See the Diagrams Nos. 9, 10, 11, 13, 17, 18, accompanying the specimens. No. 18 shows the manner in which the old lavas sometimes cut into the tuffs over which they have flowed.) From the impure limestones, fossils of Carboniferous Limestone age have been obtained, *Productus giganteus* being specially abundant. We may therefore consider the geological position of these beds as low down in the Carboniferous Limestone series; indeed, in this particular district, they form the natural and true base of that system. Wherever a good section is visible, and no faulting occurs to disturb the relations of the strata, we find the trappean series rising out from beneath the lowest bed of limestone worked throughout the district, as at Beith, Giffen, Auchentiber, Stewarton, Galston, etc., Busby, Shields, Rig, etc. This limestone usually rests upon a set of beds (the upper member of the trappean series) which varies somewhat in character and extent, the strata appearing to be made up in great measure out of the underlying porphyrites and tuffs, although in some places they exhibit true volcanic tuff with lapilli and bombs. Their most common character, however, is that of ashy-like shales, mudstones, fireclays, sandstones, and conglomerates, with which are sometimes associated ribbons of clay ironstone and thin limey bands, yielding fossils of Carboniferous Limestone age.

The underlying traps and tuffs are pierced here and there by vertical intrusions of porphyrite, basalt, and allied rocks, which appear to occupy the 'vents' or 'necks' from which some of the bedded trappean masses and tuffs have been ejected.—(See Diagram No. 9.) Among these may be enumerated Loudoun Hill; Dunwan Hill, near Eaglesham; Duncarnock, near Neilston, etc. The rock of such plugged vents or necks is usually very hard and compact, and has thus yielded less to the action of the denuding forces than the surrounding beds of porphyrite and tuff; hence the necks now come to form bold prominent crags and isolated hills.—(See Section across Loudoun Hill, Diagram No. 13.)

Window Case, 36.

The general structure of the district is simple: the trappean rocks form a broad, undulating, anticlinal arch or saddleback, stretching north-west and south-east, and throwing off the carboniferous basin of Lanarkshire to the north, and the broken and interrupted basins of the Ayrshire coalfields to the south.—(See Sketch-section No. 9.) The following specimens (224–461) do not by any means exhaust the varieties of igneous rocks to be met with in the district they are meant to illustrate. All the important varieties, however, are present; and the collection represents very fairly the general character of the trappean masses which form the base of the Carboniferous Limestone series. The old lavas occupy by much the larger proportion of the surface throughout this region of igneous rocks, the tuffs and volcanic agglomerates being confined for the most part to its southern termination, where they appear to lie at no great distance below the main or lowest limestone.—(See Diagram No. 9.) The tuffs and agglomerates also make their appearance in some force in the neighbourhood of Eaglesham, in Renfrewshire, and seem to occupy there the same relative position. If we except a few lenticular beds and bands of tuff, intercalated here and there among the old volcanic lavas, the only rocks which are seen at the surface throughout the greater part of this district are anamesite, basalt, melaphyre, and porphyrite.

224–239. ANAMESITES.—These rocks have a dark-coloured crystalline felspathic base, with augite in variable proportions. They are much less basic than the anamesites, which occur either as bedded masses or intrusive sheets among the coal measures. They also contain less augite than the vertical veins and dykes of anamesite, basalt, and dolerite of tertiary age.—(See Case 43, p. 85.)

224. Anamesite.

Townhead of Gabrochill, Dunlop, Ayrshire.

This and the succeeding specimens (224 to 235) exhibit a rudely lamellar or flakey arrangement of the felspar crystals. Owing to this structure, these rocks have a tendency to split with an irregular fissile or schistose fracture.

225. Anamesite.

Craignaught, Dunlop, Ayrshire.

226. Anamesite.

Townhead of Gabrochill, Dunlop, Ayrshire.

227. Anamesite.

Craignaught Hill, Dunlop, Ayrshire.

228. Anamesite.

Near the Totherick, Dunlop, Ayrshire.

229. Anamesite.

Tofts, Eaglesham, Renfrewshire.

230. Anamesite.

County Boundary, near Gabrochill, Ayrshire.

231. Anamesite.

Eaglesham, Renfrewshire.

232. Anamesite.

Townend of Fullwood, Dunlop, Ayrshire.

233. Anamesite.

Grange, near Lugton, Ayrshire.

Window Case, 36.

234. Anamesite.

West Halket, Lugton, Ayrshire.

235. Anamesite.

Mooryet Plantation, Eaglesham, Renfrewshire.

236. Anamesite.

Craigs of Neilston, Renfrewshire.

237. Anamesite.

Burnie Craigs, Kingston, Craignaught, Dunlop, Ayrshire.

238. Anamesite.

Craigs of Neilston, Renfrewshire.

239. Anamesite.

Bourock Quarry, near Dunlop, Ayrshire.

240–245. BASALTS.—These specimens illustrate the character of the bedded basalts. They are usually fine-grained or compact, hard, heavy rocks, often containing much olivine and magnetic iron. They do not appear to differ essentially from the basalts of later carboniferous and tertiary age.—(See Cases 42–44.)

Window Case, 37.

240. Basalt.

Borland, Dunlop, Ayrshire.

Hard, compact, heavy, with a little olivine.

241. Basalt.

Ryeburn, Dunlop, Ayrshire.

Hard, crypto-crystalline base, with a little olivine scattered through it.

242. Basalt.

Bell Craig Quarry, Mearns, Renfrewshire.

243. Basalt.

Craig of Neilston, Neilston, Renfrewshire.

With much olivine.

244. Basalt.

Dunlop, Ayrshire.

A little olivine scattered through the base.

245. Basalt.

Baird's Knowe, Eaglesham, Renfrewshire.

246–296. MELAPHYRES.—These rocks consist usually of a bluish or reddish felspathic base, containing a variable admixture of a pyroxenic mineral, perhaps augite. Sometimes this mineral becomes very abundant, and the rocks then assume quite a doleritic aspect (see No. 261). As a general rule, however, the pyroxene does not enter very abundantly into the composition of these rocks, and it is usually in a decomposed condition. The base is frequently serpentinous. The melaphyres vary from fine-grained, almost compact rocks, to coarsely crystalline and amygdaloidal masses. They are usually porphyritic with oligoclase, sometimes with orthoclase, and frequently very abundantly so with a ferruginous mineral ('ferrite'). Occasionally they contain olivine. The upper portions of a bed are generally amygdaloidal, slaggy, and scoriaceous, and often concretionary, with an abundance of chalcedony, and an amorphous dark-green serpentinous mineral. The middle portion is less amygdaloidal, while the bottom resembles the top in its slaggy and scoriaceous character. These melaphyres differ from the melaphyres and dolerites so commonly met with among carboniferous strata, not only in their less basic character, but in texture, in the character of the minerals with which

Window Case, 37.

they are rendered porphyritic, in their manner of jointing, and the mode in which they yield to the influence of the weather. They are, indeed, connecting links between the usual melaphyres, basalts, dolerites, etc., and the porphyrites (Nos. 297–386). In the more basic varieties they approach the nature of dolerites, and assume the character of porphyrites when they contain but little pyroxene.

246. Melaphyre.

Glen Water, near Carling Craig, Renfrewshire.

247. Melaphyre.

Near Craighead Law, Dunlop, Ayrshire.

248. Melaphyre.

Laggan Hill, Longloch, Renfrewshire.

249. Melaphyre.

Binend Hill, Renfrewshire.

250. Melaphyre.

Dunlop, Ayrshire.

251. Melaphyre.

Hillend, Dunlop, Ayrshire.

252. Melaphyre.

Stanelymoor, south of Paisley, Renfrewshire.

253. Melaphyre.

Near Millthird, Crofthead, Renfrewshire.

254. Melaphyre.

Sidehead, Dunlop, Ayrshire.

255. Melaphyre.

East Law, Broomhill, near Loudoun Hill, Ayrshire.

256. Melaphyre.

East Law, Broomhill, near Loudoun Hill, Ayrshire.

[See diagram accompanying specimen.]

257. Melaphyre.

West Halket, by Dunlop, Ayrshire.

258. Melaphyre.

Rivoch, Eaglesham, Renfrewshire.

259. Melaphyre.

Tandlehill, near Dunlop, Ayrshire.

260. Melaphyre.

Roadside Quarry, near Bannerbank, Brother Loch, Renfrewshire.

261. Melaphyre.

Roadside, Knavock Law, Darvel, Ayrshire.

262. Melaphyre.

Westhills, Cathkin, Renfrewshire.

263. Melaphyre.

Westhills, Cathkin, Renfrewshire.

264, 264a. Melaphyre.

Westhills, Cathkin, Renfrewshire.

263, 264, 264*a*, are taken from different portions of the same bed.

265. Melaphyre.

Mearns Muir, Eaglesham, Renfrewshire.

266. Melaphyre.

Near Carling Craig, Glen Water, Ayrshire.

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267. Melaphyre.

Nether Craig, White Cart, Eaglesham, Renfrewshire.

268. Melaphyre.

Knockend Plantation, near Neilston, Renfrewshire.

269. Melaphyre.

Near Kingston, Dunlop, Ayrshire.

270. Melaphyre.

Barrance Hill, Brother Loch, Renfrewshire.

271. Melaphyre.

Glen Water, Darvel, Ayrshire.

272. Melaphyre.

High Borland, Eaglesham, Renfrewshire.

273. Melaphyre.

Near Stanelymoor, Gleniffer Braes, Renfrewshire.

274. Melaphyre.

Blacksnip Plantation, Grange, Dunlop.

275. Melaphyre.

Tandlehill, near Dunlop, Ayrshire.

276. Melaphyre.

Near Stanelymoor, Gleniffer Braes, Renfrewshire.

277. Melaphyre.

Window Case, 38.

Faside Quarry, Mearns, Renfrewshire.

278. Melaphyre.

Upper Threepland, Eaglesham, Renfrewshire.

279. Melaphyre.

West Halket, near Dunlop, Ayrshire.

280. Melaphyre.

Gleniffer Braes, Renfrewshire.

281. Melaphyre.

Enoch Burn, Eaglesham, Renfrewshire.

282. Melaphyre.

Enoch Burn, Eaglesham, Renfrewshire.

283. Melaphyre.

Road to Glasgow, a quarter of a mile from Eaglesham, Renfrewshire.

The rock is sparingly amygdaloidal.

284. Melaphyre.

Straum Hill, Renfrewshire.

285. Melaphyre.

Fáside, Mearns, Renfrewshire.

286. Melaphyre.

Cuff, near Beith, Renfrewshire.

287. Melaphyre.

Duchallaw, Crofthead, Renfrewshire.

288. Melaphyre.

Craigs of Neilston, Renfrewshire.

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289. Melaphyre.
Blacksnip Plantation, Grange, Renfrewshire.

290. Melaphyre.
Harelaw Reservoir, Crofthead, Renfrewshire.

291. Melaphyre.
Stanelymoor, Gleniffer Braes, Renfrewshire.

292. Melaphyre.
Near Harelaw Reservoir, Crofthead, Renfrewshire.

293. Melaphyre.
Near Dod Hill, Neilston, Renfrewshire.

294. Melaphyre.
Back Thornlymuir, Gleniffer Braes, Renfrewshire.

295. Melaphyre.
Newhouse, Gateside, Beith, Ayrshire.

296. Melaphyre.
Harelaw Reservoir, Crofthead, Renfrewshire.

297–386. PORPHYRITES.—These rocks are distinguished from the preceding series of melaphyres by negative characters only. The felspathic base contains no pyroxenic mineral, at least in the more typical varieties; yet, in general appearance, these porphyrites closely resemble the melaphyres. They are usually of a blue, red, or brown colour, sometimes pale grey or white. The texture is commonly fine-grained and dull, often earthy, and not infrequently meagre to the touch. It is sometimes difficult to distinguish them in hand specimens from felspathic tuffs. But from these dull, homogeneous, fine-grained porphyrites, there is every variety up to coarsely crystalline rocks. Nearly all are more or less porphyritic, the minerals scattered through the base being commonly oligoclase, sometimes orthoclase, and a highly ferruginous mineral ('ferrite'). Occasionally, like the melaphyres, they contain olivine. The upper and under surfaces of the beds also frequently exhibit the slaggy and scoriaceous aspect presented by the melaphyres.—(See Diagram No. 12 accompanying specimens, for section of a bed of porphyrite showing slaggy and scoriaceous character of the bottom of the bed.) Many of the porphyrites are highly amygdaloidal, and very coarsely porphyritic, the amygdaloidal cavities being filled with calcspar, decomposed serpentinous minerals, chalcedony, etc. Although the more typical porphyrites are easily distinguished from the melaphyres, yet they frequently contain a small proportion of decomposing pyroxene, and thus pass into melaphyre.

297. Porphyrite.
Black Law, Dunlop, Ayrshire.

298. Porphyrite.
Holehall Burn, Eaglesham, Renfrewshire.

299. Porphyrite.
Aitket's Mill, Dunlop, Ayrshire.

300. Porphyrite.
Black Loch Burn (Quarry), Renfrewshire.

301. Porphyrite.
Chapel Craig, Dunlop, Ayrshire.

302. Porphyrite.
Whitehill, Mearns, Renfrewshire.

303. Porphyrite.
Corsbie Craigs, Dunlop, Ayrshire.

304. Porphyrite.
East Moorhouse, Eaglesham, Renfrewshire.

305. Porphyrite.
Craighead Law, Dunlop, Ayrshire.

306. Porphyrite.
Craighead Law, Dunlop, Ayrshire.

307. Porphyrite.
Brownside Braes, south of Paisley, Renfrewshire.

308. Porphyrite.
Glanderston Dam, Neilston, Renfrewshire.

309. Porphyrite.
Foreside, Crofthead, Renfrewshire.

310. Porphyrite.
Foreside, Crofthead, Renfrewshire.

311. Porphyrite.
Enoch Burn, Eaglesham, Renfrewshire.

312. Porphyrite.
Cowden Hall, Crofthead, Renfrewshire.

313. Porphyrite.
Holehall Burn, Eaglesham, Renfrewshire.

314. Porphyrite.
Ballagioch Hill, Eaglesham, Renfrewshire.

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315. Porphyrite.
Brockburn, Balgray House, Renfrewshire.

316. Porphyrite (porphyritic with orthoclase).
Near High Grange, Dunlop, Ayrshire.

317. Porphyrite (same as 316).
Near Grange, Dunlop, Ayrshire.

318. Porphyrite.
West of Stanelymoor, Gleniffer Braes.

319. Porphyrite.
Quarry, Meikle Binend, Renfrewshire.

320. Porphyrite.
Enoch Burn, Eaglesham, Renfrewshire.

321. Porphyrite.
Little Hill, near Caldwell.

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322. Porphyrite.
Brockburn, near Balgray House, Renfrewshire.

323. Porphyrite.
Near Polloktown, Renfrewshire.

324. Porphyrite.
Bellsgrove, near Beith, Ayrshire.

325. Porphyrite (same as 320).
Enoch Burn, Eaglesham, Renfrewshire.

326. Porphyrite.
Binend Burn, Renfrewshire.

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327. Porphyrite.
Near Driffenbeg, Renfrewshire.

328. Porphyrite.
Barnhill, Newmilns, Ayrshire.

329. Porphyrite.
Glanderston Mains, Neilston, Renfrewshire,

330. Porphyrite.
Glanderston Dam, Neilston, Renfrewshire.

331. Porphyrite.
Glanderston Mains, Neilston, Renfrewshire.

[332–341. These porphyrites show peculiar ferruginous discolourations, some of which assume undulating and ring-shaped appearances. The discolourations appear to be due to the partial weathering of a felspar.]

332. Porphyrite.
Duchallan, Crofthead, Renfrewshire.

333. Porphyrite.
Black Hill, Renfrewshire.

334. Porphyrite.
Black Hill, Renfrewshire.

335. Porphyrite.
Quarry at Roadside, Park, Eaglesham, Renfrewshire.

336. Porphyrite.
Cuff Hill, Beith, Ayrshire.

337. Porphyrite.
Dod Hill, Neilston, Renfrewshire.

338. Porphyrite.
Near Duchallaw, Crofthead, Renfrewshire.

339. Porphyrite.
Near Little Byres, above Darvel, Ayrshire.

340. Porphyrite.
Cairnhill, Black Loch, Renfrewshire.

341. Porphyrite.
Black Law, Dunlop, Ayrshire.

342. Porphyrite.
High Overmnir, north of Darvel, Ayrshire.

343. Porphyrite.
Neilston Pad, Renfrewshire.

344. Porphyrite.
Ryeburn, near Dunlop, Ayrshire.

345. Porphyrite.
Rakerfield, near Beith, Ayrshire.

346. Porphyrite.
Rakerfield, near Beith, Ayrshire.

347. Porphyrite.
Black Hill, Renfrewshire.

348. Porphyrite.
Huntlawrig, Eaglesham, Renfrewshire.

349. Porphyrite.
Huntlawrig, Eaglesham, Renfrewshire.

350. Porphyrite.
Byreside Hill, Brother Loch, Renfrewshire.

351. Porphyrite.
Rivoch Cut, Eaglesham, Renfrewshire.

352. Porphyrite.
Brownmuir Plantation, Eaglesham, Renfrewshire.

353. Porphyrite.
Ballagioch Hill, Eaglesham, Renfrewshire.

354. Porphyrite.
Dunlop Hill, Ayrshire.

355. Porphyrite.
Binend Hill, Renfrewshire.

356. Porphyrite.
Commore Dam, Neilston, Renfrewshire.

This rock is somewhat scoriaceous.

357. Porphyrite.
Corsbie Craigs, Dunlop, Ayrshire.

Rock shows curious, irregular, wavy laminæ of decomposed felspar.

358. Porphyrite.
Glen Water, Darvel, Ayrshire.

359. Porphyrite.
Near High Walton, Neilston, Renfrewshire.

360. Porphyrite.
Tongue Burn, Darvel, Ayrshire.

361. Porphyrite.
East Carrot Burn, Eaglesham, Renfrewshire.

362. Porphyrite.
Bellsgrove Hill, Beith, Ayrshire.

From slaggy upper surface of a bed of porphyrite.

363. Porphyrite.
Dingle Bog, Neilston, Renfrewshire.

From slaggy upper surface of a bed of porphyrite.

Window Case, 39.

364. Porphyrite.
White Cart, near Huntlawrig, Eaglesham, Renfrewshire.

Slaggy, amygdaloidal, scoriaceous rock.

365. Porphyrite.
Glen Water, Darvel, Ayrshire.

366. Porphyrite.
Westhills, Cathkin, Renfrewshire.

Concretionary, slaggy, scoriaceous upper surface of old lava; some of the cavities filled with calcspar, chalcedony, etc.

367. Porphyrite.
Glen Water, Ayrshire.

Amygdaloidal and porphyritic rock.

368. Porphyrite.
Brockburn, Balgray House, Renfrewshire.

Abundantly porphyritic with oligoclase, and amygdaloidal with calcspar.

369. Porphyrite.
Near High Walton, Neilston, Renfrewshire.

370. Porphyrite.
High Grange, Kingston, near Dunlop, Ayrshire.

371. Porphyrite.
Enoch Burn, Eaglesham, Renfrewshire.

372. Porphyrite.
Dunlop, Ayrshire.

Window Case, 40.

373. Porphyrite.
Commore Dam, Neilston, Renfrewshire.

373a. Porphyrite.
Commore Dam, Neilston, Renfrewshire.

The cavities lengthened in the direction of flow of the old lava.

Window Case, 40.

374. Porphyrite.

Killoch Glen, Crofthead, Renfrewshire.

375. Porphyrite.

Holehall Burn, Eaglesham, Renfrewshire.

376. Porphyrite.

Enoch Burn, Eaglesham, Renfrewshire.

377. Porphyrite.

Near Stanelymoor, Gleniffer Braes, Renfrewshire.

378. Porphyrite.

Threepland Burn, Eaglesham, Renfrewshire.

379. Porphyrite.

Threepland Burn, Eaglesham, Renfrewshire.

380. Porphyrite.

Middleton, Crofthead, Renfrewshire.

381. Porphyrite.

Mooryetts Plantation, Eaglesham, Renfrewshire.

382. Porphyrite.

Harelaw Reservoir, Crofthead, Renfrewshire.

383. Porphyrite.

Gleniffer Braes, Renfrewshire.

384. Porphyrite.

Brownside Braes, Renfrewshire.

385. Porphyrite.

Near Stanelymoor, Gleniffer Braes, Renfrewshire.

386. Porphyrite, *showing slickensides.*

Cowdon Burn, Crofthead, Renfrewshire.

This specimen is taken from a bed of porphyrite which is much broken and shattered along a line of powerful dislocation. The slickensides are due to the rubbing together of the rock faces by the movement of the beds at the time of dislocation.

INTRUSIVE ROCKS OF CARBONIFEROUS LIMESTONE AGE.

387, 387a. Melaphyre.

East Carrot Burn, Eaglesham, Renfrewshire (two specimens).

From mass intruded among porphyrites and ashes.

388. Anamesite.

Loudoun Hill, Ayrshire.

From vertical 'plug' filling up an old volcanic neck or vent, from which some of the preceding igneous rocks (Nos. 224–386) and the succeeding tuffs (391–457) have been ejected. (See Section No. 13 accompanying specimen.)

389, 389a. Basalt.

Dunwan Hill, Eaglesham, Renfrewshire (two specimens).

From vertical 'plug' of same character as that from which 388 is taken. This rock contains olivine.

390. Anamesite.

Carline Craigs, Eaglesham, Renfrewshire.

From an intrusive boss cutting through bedded porphyrites; contains olivine.

391–459. FELSPATHIC TUFFS, ASHY GRITS, AGGLOMERATES, ETC.—These rocks occur interbedded among the melaphyres and porphyrites. They vary

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in character from fine-grained ashy mudstones, sandstones, and grits, to coarse volcanic agglomerates of porphyrite, melaphyre, etc. The beds are usually stratified, but in the coarser deposits frequently all trace of bedding is lost, and we have only a pell-mell accumulation of angular and sub-angular blocks and lapilli of melaphyres and porphyrites mixed with felspathic sand and dust. [See Sections Nos. 14, 15, 16, 17, 18.] The best districts for the study of these rocks are the valley of the Glen Water, a tributary of the river Irvine, and the neighbourhood of Eaglesham, in Renfrewshire. Many of the tuffs are as loose and incoherent as they were when first ejected; others are hard and tough, and resemble some of the dull trachytic-like porphyrites with which they are interbedded. The stones in the tuffs occasionally attain a very large size, especially in the neighbourhood of the old volcanic vents. As we recede from these centres of eruption, the lapilli become smaller, and the tuffs finer-grained and better stratified. Associated with these finer-grained deposits, we not unfrequently come upon beds of sandstone and shale, with thin bands of clay-ironstone, and impure limestone, containing fossils. Bands of *Productus giganteus* also occur in the same position. Sections Nos. 9 and 10 show the manner in which a large block of porphyrite ejected from an old volcanic vent has pressed down the layers of soft yielding felspathic mud and sand on which it fell.

391–393. **Felspathic Tuff** and **Ashy Mudstone,** from bed in porphyrite.

Westhills, Cathkin, Lanarkshire.

394. **Felspathic Tuff,** with small lapilli.

Glen Water, Darvel, Ayrshire.

395. **Felspathic Tuff.**

Glen Water, Darvel, Ayrshire.

396. **Felspathic Tuff.**

Glen Water, Darvel, Ayrshire.

397. **Felspathic Tuff.**

Little Byres, near Darvel, Ayrshire.

398. **Felspathic Tuff.**

Glen Water, Ayrshire.

399. **Felspathic Tuff.**

Glen Water, Darvel, Ayrshire.

400. **Felspathic Tuff.**

Glen Water, Darvel, Ayrshire.

401. **Felspathic Tuff.**

Glen Water, near Darvel, Ayrshire.

402. **Felspathic Tuff.**

Glen Water, near Darvel, Ayrshire.

403. **Felspathic Tuff.**

Near Carling Craig, Glen Water, Ayrshire.

404. **Felspathic Tuff.**

Glen Water, Ayrshire.

405. **Felspathic Tuff.**

Glen Water, Ayrshire.

406. **Felspathic Tuff.**

Glen Water, Ayrshire.

407. **Felspathic Tuff.**

Glen Water, Ayrshire.

408. **Felspathic Tuff.**

Glen Water, Ayrshire.

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409. Felspathic Tuff.
Glen Water, Ayrshire.

410. Felspathic Tuff.
Glen Water, Ayrshire.

411. Felspathic Tuff.
Glen Water, Ayrshire.

412a. Felspathic Tuff.
Glen Water, Ayrshire.

412b. Felspathic Tuff.
Glen Water, Ayrshire.

413. Felspathic Tuff.
Glen Water, Carling Craig, Ayrshire.

414. Felspathic Tuff.
Glen Water, Ayrshire.

415. Felspathic Tuff.
Glen Water, Darvel, Ayrshire.

416. Felspathic Tuff.
Cuddy's Cairn, Glen Water, Ayrshire.

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417. Felspathic Tuff.
Glen Water, Ayrshire.

418. Felspathic Tuff.
Glen Water, Ayrshire.

419. Felspathic Tuff.
Glen Water, Ayrshire.

420. Felspathic Tuff.
Glen Water, Ayrshire.

421. Felspathic Tuff.
Glen Water, Ayrshire.

422. Felspathic Tuff.
Glen Water, Ayrshire.

423. Felspathic Tuff.
Glen Water, Ayrshire.

424. Felspathic Tuff and **Ashy Sandstone.**
Glen Water, Ayrshire.

425. Felspathic Tuff.
Glen Water, Ayrshire.

426. Felspathic Tuff.
Glen Water, Ayrshire.

427. Felspathic Tuff.
Glen Water, Ayrshire.

428. Felspathic Tuff.
Carnal Castle, Muck Water, Darvel, Ayrshire.

429. Felspathic Tuff.
Muck Water, near Darvel, Ayrshire.

430. Felspathic Tuff.
Muck Water, near Darvel, Ayrshire.

431. Felspathic Tuff.
Near Muck Bridge, Darvel, Ayrshire.

432. Ashy Grit, with carbonaceous matter.
Muck Water, near Darvel, Ayrshire.

433. Felspathic Tuff.
Carnal Castle, Muck Water, near Darvel, Ayrshire.

434. Felspathic Tuff.
Tulloch Burn, near Darvel, Ayrshire.

435. Felspathic Tuff.
Tulloch Burn, near Darvel, Ayrshire.

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436. Felspathic Tuff.
Tulloch Burn, near Darvel, Ayrshire.

437. Felspathic Tuff.
Tongue Burn, Passford, near Darvel, Ayrshire.

438. Felspathic Tuff.
Tongue Burn, Harelea Hill, near Darvel, Ayrshire.

439. Felspathic Tuff.
East Glaister, River Irvine, above Darvel, Ayrshire.

440. Felspathic Tuff.
Broomhill Farm, near Darvel, Ayrshire.

441. Felsapthic Tuff.
Enoch Burn, Eaglesham, Renfrewshire.

442. Felspathic Tuff.
Enoch Burn, Eaglesham, Renfrewshire.

443. Felspathic Tuff.
Enoch Burn, Eaglesham, Renfrewshire.

444a. Felspathic Tuff.
Enoch Burn, Eaglesham, Renfrewshire.

444b. Felspathic Tuff.
Enoch Burn, Eaglesham, Renfrewshire.

445. Felspathic Tuff.
Enoch Burn, Eaglesham, Renfrewshire.

446a. Felspathic Tuff.
Carrot Burn, Eaglesham, Renfrewshire.

446b. Lapilli, from Tuff.
Carrot Burn, Eaglesham, Renfrewshire.

447a. Felspathic Tuff.
Carrot Burn, Eaglesham, Renfrewshire.

447b. Felspathic Tuff.
Carrot Burn, Eaglesham, Renfrewshire.

448. Felspathic Tuff.
Carrot Burn, Eaglesham, Renfrewshire.

449. Felspathic Tuff.
East Carrot Burn, Eaglesham, Renfrewshire.

450. Felspathic Tuff.
East Carrot Burn, Eaglesham, Renfrewshire.

451. Felspathic Tuff.
Harelaw, White Cart, Eaglesham, Renfrewshire.

452. Felspathic Tuff.
Holehall Burn, Eaglesham, Renfrewshire.

453. Felspathic Tuff.
Honestly Mount, Eaglesham, Renfrewshire.

454. Felspathic Tuff.
Rivoch Cut, Eaglesham, Renfrewshire.

455. Ashy Mudstone.
Binend Burn, Eaglesham, Renfrewshire.

456. Felspathic Tuff.
Black Loch, Renfrewshire.

Window Case, 41.

457. Felspathic Tuff.

Threepland Burn, Eaglesham, Renfrewshire.

458. Granite, *from Block in Ash.*

Enoch Burn, Eaglesham, Renfrewshire.

From a block embedded in ashy agglomerate. In its immediate neighbourhood, blocks and lapilli of the same rock are rather plentiful; from which it may be inferred, that at some depth below the surface of this region, there probably exists a mass of granite. But whether this is a prolongation of the crystalline rocks of the northern Highlands, or a continuation of the granite and other altered rocks (of Lower Old Red Sandstone age), which are met with at Watstone Hill and its neighbourhood, near the head of the River Irvine (see Window Case 33, Nos. 80–99), can only be conjectured.

459. Felspathic Tuff.

Broomhill, Dundonald, Ayrshire.

The beds immediately below the main limestone in this district (Galston, Stewarton, Beith, Caldwell, Busby, etc.) consist of ashy grits, sandstones, and shales, with conglomerates. These beds are made up of the triturated remains of the underlying porphyrites and melaphyres and tuffs, but sometimes contain intercalated tuffs and agglomerates of volcanic origin.—(See Diagrams 9, 19, 20, 21, accompanying specimens.)

460. Ashy Grit.

Easter House, Meikle Corsehill, Stewarton.

Bed underlying the main limestone.

461. Pavement of Limestone, resting on Ashy Grit.

Kittoch Water, Ayrshire.

(Diagrams Nos. 13 and 14 accompanying specimen.)

462. Encrinital Limestone.

Garpal Water.

[From Kilmarnock westward, the upper extension of the Carboniferous Limestone series is well-marked by a bed of dolerite of variable thickness, with which is associated a set of tuffs and ashy-like shales and fireclays, some of which are highly impregnated with carbonate of iron.]

Window Case, 42.

COAL MEASURES.

463. Limestone, with *spirorbis carbonarius.*

Ballochmyle, Ayrshire.

This seam occurs in the upper non-coal-bearing part of the Ayrshire Coal Measures.

464. Coal, full of teeth, scales, and bones of megalicthys, etc.

Lanemark Coal Pit, New-Cumnock, Ayrshire.

From a thin 'bone-bed' lying in the coal-seam.

465–468. Columnar Coal.

Chalmerston Glen, Dalmellington.

These four specimens illustrate the alteration effected on this coal-seam by the contact of the overlying intrusive dolerite (Nos. 476, 477). Nos. 465–468 are taken from the upper part of the bed of coal immediately below the dolerite. The coal has been coked, and in the process has been rendered columnar, the pencil-like columns being directed perpendicularly to the surface of the dolerite.

469, 470. Columnar Coal.

Rogerton, Auchinleck.

In these two specimens also (altered

Window Case, 42.

by dolerite No. 478) there is the same conversion of the coal into a kind of prismatic coke by the contact of the heated dolerite.—(See Diagram No. 22 accompanying specimen.)

471. Columnar Coal.

Crossflat Pit, Muirkirk.

Coal altered by dolerite as in preceding specimens.

472, 473. Columnar and Broken Coal, mixed with hardened clay, shale, etc.

Engine Pit, Garpel Water, near Muirkirk, Ayrshire.

Alteration and confusion caused by intrusion of dolerite.

474. Columnar Coal, showing junction with Dolerite.

Wellwood Big Pit, Muirkirk, Ayrshire.

475. Columnar Coal.

Spireslack Pit, Glenluck, near Muirkirk, Ayrshire.

Altered by contact with dolerite (No. 479).

INTRUSIVE DOLERITE BEDS AND BOSSES IN CARBONIFEROUS AND PERMIAN ROCKS.

The Carboniferous and Permian strata of Ayrshire contain sheets of igneous rock (dolerite, etc.) which have been intruded among the sandstones, shales, and coals with which they are associated.—(See Sections in Case, Nos. 22 to 29.) These intrusive rocks are crystalline in texture, and have generally a blue or green colour. The strata among which they occur usually show marks of having been subjected to great heat. The sandstones and shales are hardened, the fireclays are baked, and the coals are often converted into a kind of coke, or entirely consumed to a black dust. Nos. 469–475 exhibit the general character of coal near which a sheet of dolerite has been intruded. Dolerite, when it comes in contact with coal or carbonaceous shale, usually becomes dirty green, grey, or white. Nos. 476–479 illustrate this peculiarity. The thickness of these intrusive sheets varies from a few inches to many feet. They are often found in great numbers in the coalfields, occupying the position of the coals which they have destroyed.—(See Section in Case, No. 23.) A coal-seam thus appears to have been a line of weakness along which the melted rock was prone to intrude.

476, 477. 'White Trap' (dolerite).

Chalmerston Glen, Dalmellington.

The dolerite which burns and cokes the coal-seams is usually of a bluish or greenish-blue colour at some distance from the coal-seam, but as it approaches the coal it becomes discoloured, and acquires the character illustrated by these and the succeeding specimens. The dolerite from which these specimens are taken alter the 'Sillyhole Coal-seam' at Dalmellington (Nos. 467, 468).

478. 'White Trap' (dolerite).

Rogerton, Auchinleck, Ayrshire.

Taken from a thin intrusive sheet which alters the seam of coal known as the 'Claud Coal' (Nos. 469, 470).

479. Dolerite, soft, decomposed to a white clay.

Spireslack Pit, Glenbuck, near Muirkirk, Ayrshire.

The intrusive dolerite from which this specimen comes alters a coal-seam into a kind of coke (No. 475).

Window Case, 42.

480, 481. Dolerite.

Whitehill, Dalmellington, Ayrshire.

482. Dolerite.

Carskeoch, Patna, Ayrshire.

This rock pierces a 'neck' or old plugged volcanic vent of Permian age.

483. Dolerite.

Quarry Knowe, Patna.

484. Dolerite.

Half mile west of Grimmet, Dalmellington.

485. Dolerite.

Grimmet, Dalmellington.

486. Dolerite.

Hare Craig, Dalmellington.

487. Dolerite.

Craigmark Hill, Dalmellington.

488. Dolerite.

Drumgrange, Dalmellington.

489. Dolerite.

Lethan Hill, Waterside, Dalmellington.

490, 491. Dolerite.

Chalmerston Hill, Dalmellington.

492. Dolerite.

Benbranachan, Dalmellington.

493, 494. Dolerite.

Benbeoch, Dalmellington.

495–498. Dolerite.

Kilmein Hill, Dalmellington.

These specimens are taken from different parts of the same large mass of intrusive dolerite.—(See Section No. 27 accompanying specimen.)

499. Dolerite.

Corbie Craigs, Waterside, Dalmellington.

500. Dolerite.

Rough Burn, Dalmellington.

501. Dolerite.

Lochluie Hill, Dalmellington.

502. Dolerite.

Pennyarthur, Dalmellington.

503. Dolerite.

Lugar Water, near Logan Bridge.

504. Dolerite.

Dalcairnie Burn, Dalmellington.

505. Dolerite.

Dalnean Craig, Dalmellington.

506. Dolerite.

Broadhirst, Dundonald.

507. Dolerite.

Dundonald.

508. Dolerite.

Townend, Symington.

509. Dolerite.

Parkthorn Quarry, Troon.

510. Dolerite.

Howford Bridge, Ballochmyle.

This rock cuts through the ridge of the

Permian basin. It is traversed by veins of a coarser texture, of which the next specimen is a sample.

511. Dolerite.

Howford Bridge, Ballochmyle.

From vein traversing the dolerite No. 510.

Window Case, 42.

512. Dolerite.

Junction of Greenock Water with River Ayr.

513. Dolerite.

Whitehaugh Water, Garpel House.

514. Basalt.

Middlefield Law, Muirkirk.

PERMIAN.

Window Case, 43.

The Permian formation of Ayrshire consists of—

1st, A series of bright brick-red coloured sandstones, resting upon and graduating down into—

2d, A set of volcanic tuffs with which are associated beds of porphyrite and melaphyre.

3d, Vertical columns or pipes of coarse agglomerate, ash, etc., the old 'necks' or vents through which the volcanic materials of this epoch were ejected. (See Sections Nos. 30 and 31 in Case.)

515. Melaphyre-tuff.

Ballochmyle.

A coarse gravelly mixture of fragments of melaphyre, etc., in a dull-red earthy base. This rock lies at the base of the Permian group. It is well-bedded, some of its layers being coarse and full of stones; others much finer in texture, and passing into the ordinary brick-red sandstone of the Permian series.

516. Eight Stones from Melaphyre-tuff.

Ballochmyle.

The rough, irregular form of these little volcanic stones is illustrated in this series of specimens. They are all amygdaloidal, as shown in the fractured surfaces of those which have been broken.

517. Junction of Sandstone and Tuff.

Ballochmyle.

In this specimen the lower surface shows a coarse gravelly tuff, full of little slaggy fragments, above which comes red sandstone, through which there is diffused a large quantity of fine volcanic dust. The lower layer marks where a shower of dust and lapilli had settled down upon the sea-bottom, while the sandstone above indicates the continuance of the ejection of fine dust while the ordinary sandy sediment was being laid down over the coarser tuff.

518. Melaphyre-tuff.

Mossgiel Railway Cutting.

519. Sandy Melaphyre-tuff.

Mossgiel Railway Cutting.

Nos. 518 and 519 are taken from the tuffs which lie at the bottom of the Permian basin on its northern margin. They show the same gravelly mixture of volcanic fragments with sandy sediment so well seen on the south side at Ballochmyle.

520. Melaphyre.

Mauchline Hill.

A finely crystalline rock containing a few scattered crystals of augite, and a considerable proportion of a red decomposing mineral.

Window Case, 43.

521. Melaphyre.

Barnweill Hill, north-east of Ayr.

A dark compact finely-crystalline rock, containing a large admixture of the same red mineral as in 520, and a few cavities filled with steatite.

522. Melaphyre, from vein in similar melaphyre as preceding specimen.

Barnweill Hill, Ayr.

Compact dark finely-crystalline rock, with a few kernels of steatite.

523. Melaphyre.

Ballochmyle.

Compact dark finely-crystalline, with abundant ferrite.

524. Amygdaloidal Melaphyre.

Mauchline Hill.

Cavities filled with steatite, parts of which are much decomposed.

525. Amygdaloidal Melaphyre.

Barnweill Hill.

The cavities are filled with calcite, analcime, and steatite.

526. Amygdaloidal Melaphyre.

Barnweill Hill.

527. Amygdaloidal Melaphyre.

Barnweill Hill.

528. Amygdaloidal Melaphyre.

Mossgiel Railway Cutting.

Cavities filled and lined with calcite.

529. Amygdaloidal Melaphyre.

Cairngillan, Tarbolton.

Cavities filled with calcspar and steatite.

530. Amygdaloidal Melaphyre.

Ballochmyle.

Decomposing rock, its cavities filled with carbonate of lime, steatite, etc.

531. Melaphyre - agglomerate.

Barnweill Hill.

This specimen is taken from a small 'neck' or volcanic vent which pierces the melaphyre beds of Barnweill Hill. It consists of rough fragments of melaphyre wrapped up in a matrix of red felspathic sand.

532. Melaphyre - agglomerate.

Heugh Mill, east of Monkton.

A rough breccia of different melaphyres in a compact earthy base.

533. Melaphyre - agglomerate.

Heugh Mill, east of Monkton.

534. Melaphyre - agglomerate.

Helenton Hill, east of Monkton.

A rough gravelly breccia, the volcanic origin of which is very marked, even in a hand specimen.

535. Melaphyre - agglomerate.

Chapel Hill, Patna.

From a 'neck' which comes through the sandstones and shales of the carboniferous limestone series.

536. Melaphyre - agglomerate.

Chapel Hill, Patna.

Finer in texture than 535; contains a few disseminated plates of black mica.

537. Melaphyre-tuff.

Dalmellington.

A fine ashy rock from 'neck' traversing coal measures. The coal-seams were found to be 'burnt' as the miners approached this rock.

538. Slag-like Melaphyre.
Helenton Hill, near Monkton.

This specimen is from a mass of coarse slaggy melaphyre which has risen through one of the 'necks,' and is now found adhering to the side of the agglomerate by which the neck is filled up.

539. Melaphyre, finely amygdaloidal, from 'neck.'
Carskeoch, Patna.

540. Melaphyre, finely amygdaloidal, from 'neck.'
Carskeoch, Patna.

541. Melaphyre, finely amygdaloidal, from 'neck.'
Carskeoch, Patna.

542. Altered Sandstone and **Shale** from melaphyre in 'neck.'
Carskeoch, Patna.

543. Melaphyre from 'neck.'
Knockannot, Waterside, Dalmellington.

(See Section in Case.)

544. Melaphyre from 'neck.'
Knockannot, Waterside, Dalmellington.

Portion of same rock as 543.

545. Melaphyre-tuff from 'neck.'
Knockannot, Dalmellington.

546. Melaphyre-tuff from 'neck.'
Green Hill, Waterside.

This 'neck' pierces the coal measures. —(See Section No. 31 in Case.)

Window Case, 43.

547. Hardened Sandstone from melaphyre agglomerate in 'neck.'
Green Hill, Waterside.

548. Ashy Sandstone from 'neck.'
Sillyhole, Dalmellington.

A finer-grained portion of the same rock as 537.

549. Melaphyre-tuff from 'neck.'
Sillyhole, Dalmellington.

Same as 537.

550. Melaphyre-tuff from 'neck.'
Patna Hill, Patna.

551. Melaphyre-tuff from 'neck.'
Kilmaurs.

552. Melaphyre from melaphyre-tuff in 'neck.'
Kilmaurs.

553. Sandstone.
Ballantrae.

A small detached area of Permian sandstones and conglomerate and breccia occurs at Ballantrae. This and the succeeding specimen show the characteristic colour and texture of the Permian sandstones of Ayrshire.

554. Sandstone.
Ballochmyle.

This specimen shows the characteristic colour of the sandstones of the Permian basin of Ayrshire.

555. Conglomerate.
Ballantrae.

LATER (MIOCENE?) DOLERITE DYKES.

Throughout Ayrshire a series of vertical walls or dykes of dolerite traverse the strata in a direction north-west and south-east, and sometimes north and south. They are found cutting rocks of Silurian, Carboniferous, and Permian age alike.

Window Case, 43. It is inferred that these intrusive walls of dolerite are connected with the doleritic plateaux of Antrim and the Western Islands of Scotland, and that they are probably of Miocene age.—(See Section No. 32 in Case. This Section is drawn on a true scale, six inches to one mile.)

556. Dolerite.

Craighead, near Girvan.

This dyke traverses an altered Lower Silurian rock. It has been quarried for a considerable distance into a hill-side, and the fissure has thus been re-opened up which the melted dolerite rose.

557. Dolerite.

Shore, Ardmillan.

This dyke traverses Lower Silurian strata on the beach, and the specimen shows how it suffers from weathering.

558. Dolerite.

South side of Bracken Bay, near Heads of Ayr.

559. Dolerite.

South side of Bracken Bay, near Heads of Ayr.

560. Dolerite.

Deil's Dyke, two and a half miles south-west of Ayr.

This dyke forms a promontory to the south of Greenan Castle, and cuts through and alters a part of the Calciferous Sandstone series.

561. Altered Shale.

Side of dolerite, Deil's Dyke, Shore, two and a half miles south-west of Ayr.

562. Dolerite.

Meikle Corsehill, Stewarton.

Window Case, 44.

563. Dolerite.

Giffen Craigs, west of Dunlop.

564. Dolerite.

Giffen Craigs, west of Dunlop.

565. Dolerite.

East Burn, Meikle Corsehill, Stewarton.

566. Dolerite.

Gillies Hill, Caldwell.

567. Dolerite.

Gleniffer Glen, Renfrewshire.

This dyke cuts through melaphyres and porphyrites of Carboniferous Limestone age. It forms the bed of a stream, which traverses it from end to end, and has worn it down so as to form a long straight glen with steep walls of porphyrite on either side. It contains kernels of quartz, and a dark green amorphous mineral, which coats the cavities in which the quartz occurs.

568. Dolerite.

West Clerkland, Dunlop.

This dyke cuts igneous rocks belonging to the Carboniferous Limestone series.

569. Dolerite.

Over Auchentiber, Dunlop.

570. Dolerite.

Swinzie Burn, Stewarton.

571. Dolerite.

Carskeoch, Patna.

572. Dolerite.

Downie Burn, Lanfine.

Cuts Coal-measures.

573. Dolerite.

Law Bridge, Glen Water, Darvel.

574. Dolerite.

Pogiven Burn, Darvel.

Window Case, 44.

575. Dolerite.

Changue Burn, Darvel.

This dyke cuts the Lower Old Red andstone series.

576. Dolerite.

Logan Burn, Darvel.

Cuts Lower Old Red Sandstone.

577. Dolerite.

Logan Burn, Darvel.

578. Dolerite.

Tulloch Burn, Darvel.

579. Dolerite.

Tulloch Hill, Darvel.

580. Dolerite.

Carrot Burn, Eaglesham, Renfrewshire.

Cuts igneous rocks of Carboniferous Limestone age.

581. Dolerite.

Henshaw Hill, Darvel.

Cuts tuff of Carboniferous Limestone age.

582. Dolerite.

Meikle Shalloch, Dalmellington.

Cuts through conglomerate of Lower Silurian age.

583. Dolerite.

Kirklafin, Patna.

584. Dolerite.

Auchenroy, Dalmellington.

585. Dolerite.

Auchenroy, Dalmellington.

586. Dolerite.

Quarter of a mile west of Darsalloch Hill, Dalmellington.

587. Dolerite.

Kilachie Glen, Straiton.

588. Dolerite.

Kilachie Glen, Straiton.

589. Dolerite.

Near Howlone, Muirkirk.

590. Dolerite.

Douglas Water, near Parisholm.

591. Dolerite.

Middlefield Law, Muirkirk.

592. Dolerite.

Upper Reservoir, Parisholm, Muirkirk.

593. Dolerite, approaching basalt in texture.

Pennel Burn, Whitehaugh Water.

594. Dolerite.

Whitehaugh Water, above Garpel House.

SYNOPSIS

OF THE

LEADING CHARACTERS OF THE ROCKS ENUMERATED IN THE PRECEDING CATALOGUE.

ROCKS are grouped by geologists into three divisions. 1*st*, *Aqueous*, or formed under water, from sediment which has been worn off older rocks, or from the accumulated remains of plants and animals, or from materials deposited from chemical solution. In the following alphabetical list, rocks which are of aqueous origin are distinguished by **A** after their names. 2*d*, *Igneous*, or formed under the influence of subterranean heat, and either intruded in a melted state among other rocks, or thrown out at the surface in the form sometimes of lava, and sometimes of stones and ashes. Rocks of this class are marked **I** in the following pages. 3*d*, *Metamorphic*,—that is, altered by heat and chemical agency from some previous condition (either aqueous or igneous), and changed so as to assume characters that differ from those both of the ordinary aqueous and igneous groups. Metamorphic rocks are distinguished in the following list by **M** after their names.

'Altered Rock' (M).—A term employed in this catalogue to designate some varieties of metamorphic rock from Ayrshire, which vary so much in short distances that it has been found difficult to apply any definite name to them.

Amygdaloid (I).—A rock full of almond-shaped cavities, filled up with various minerals, is called an *amygdaloid*, or *amygdaloidal*. When the cavities, owing to weathering or otherwise, become empty, the texture passes into *vesicular*.

Anamesite (I).—When dolerite becomes finely crystalline, so that the component crystals are not distinctly recognisable, it is called anamesite.—(See *Dolerite.*)

Barytes. — A mineral (sulphate of baryta) frequently found in veins and cavities of rocks. — (See No. 209, p. 65.)

Basalt (I).—This name is given to the most compact dark and heavy kinds of dolerite. (See *Dolerite.*) The summit of Arthur's Seat, and the rock forming the Lion's haunch on the same hill, are examples of basalt.

Breccia (A).—A rock formed of angular stones compacted into a mass is called a *Breccia*. The word *brecciated* or *brecciform* is applied to a rock which has been broken up, and the fragments re-cemented.

Bronzite.—A form of diallage, which see.

Calcareous.—Consisting of, or largely impregnated with lime.

Cement-Stone (A).—A name given in commerce to those varieties of limestone which contain a considerable per-centage of iron, and from which cement can be made.

Chalk (A).—A form of limestone.—(See No. 358, Window Case 31.)

Coal (A).—Coal is the name given to ancient deposits of vegetable matter, which have been laid down among the stratified rocks, and converted under pressure into a black or dark brown mineral. Different varieties are known by the names of common, or household coal; splint, or steam coal; cannel, parrot, or gas coal; blind coal, etc. Some of the gas coals approach to oil-shale in character; indeed, there seems to be a true passage of the one into the other. Blind coal, on the other hand, is a kind of anthracite, or natural coke, from which (usually owing to contact with or proximity to igneous rocks) the volatile, or illuminating ingredients, have been driven off. Sometimes coal has been rendered columnar by contact with trap-rock, as may be seen in Case 42, Nos. 465-8 of the Collection.

Conglomerate (A).—When a rock consists of rounded water-worn stones, cemented together, it is called *Conglomerate.* Such a rock is simply compacted gravel, and usually indicates the former margin of some sea or lake, or the position of an old river bed.

Cornstone (A).—A compact kind of limestone, having a fine horny-like texture.

Diallage.—A mineral of the augite family, which occurs largely in some metamorphic districts, such as that of the south of Ayrshire. It sometimes unites with a felspar to form a massive rock known as *Diallage-rock,* or *Gabbro.*

Diorite (I).—A rock consisting of a distinct crystalline mixture of a triclinic felspar and hornblende. To the west of Edinburgh several masses of diorite pierce the lower carboniferous rocks, in the same way as the trappean rocks of the district generally do. But diorite is more usually found as a plutonic rock in metamorphosed regions.

Dolerite (I).—A crystalline rock consisting of Labrador felspar, augite, magnetic or titaniferous iron, sometimes with olivine, and usually with more or less carbonate of lime or of iron. It occurs as intruded masses in all the old or palæozoic formations of central Scotland, and very commonly as dykes, running in a more or less east and west direction, which are probably of tertiary age.

Felspar.—A family of minerals which are silicates of alumina, with variable admixtures of potash, soda, and lime. The varieties illustrated by this Collection are *orthoclase* (sanidine), or potash-felspar; *oligoclase,* or soda-felspar; and *labradorite,* or lime-felspar. When the base of an igneous rock is largely composed of felspar, it is said to be *felsitic;* when an aqueous rock is chiefly or conspicuously made up of felspar detritus, it is said to be *felspathic.*

Felstone (I).—A rock consisting essentially of an orthoclastic felspar base, to which is added quartz minutely diffused or segregated into granules or 'blebs.' It is sometimes porphyritic. It occurs in intrusive masses associated with porphyrites, and sometimes fills up 'necks' (volcanic vents). But its most common form of occurrence is in dykes associated with the Silurian and Old Red Sandstone formation. In such cases it is often so intimately associated with the crumpling and metamorphism of the strata, that it requires to be considered as a plutonic rock.

Fireclay (A).—A clay which can be submitted to the intense heat of a brick kiln without melting into a slag or glass. It is a silicate of alumina with a little iron, but with little or no alkaline earth. Fireclay abounds in the carboniferous system, where it usually occurs as the pavement on which the coal-seams rest.

Granite (M and I).—A crystalline rock consisting essentially of orthoclase (with oligoclase), felspar, quartz, and mica. In the metamorphic districts illustrated by the foregoing Collection, the granite passes so insensibly into other crystalline rocks, and these into unaltered sedimentary deposits, that it is probably of metamorphic origin.—(See pp. 55 and 56.)

'Green Paste Rock' (M).—A form of altered greywacke.—(See specimen No. 20, Window Case 32.)

Greywacke (A).—The sandstones of the Old Red Sandstone, Silurian, and other ancient geological formations, have frequently undergone some metamorphism or change, so as to acquire a more or less distinctly crystalline texture. They are then more compact and close-grained than ordinary sandstones, and have received the name of greywacke.

Grit (A).—When the component grains of quartz or other substance are larger than in sandstones, and are very firmly held together, the rock made up of these has been called a grit or gritstone. But a grit is only a coarse-grained sandstone.

Hæmatite.—(See Ironstone.)

Hornblendic.—Containing a large or distinct admixture of the mineral *hornblende.*

Hypersthenite, Hyperite, or **Hypersthene Rock.**—A rock consisting of a crystalline admixture of a triclinic felspar (labradorite) and hypersthene. It is associated with metamorphic rocks in Ayrshire, where it appears to be itself also of metamorphic origin.

Ironstone (A).—This term is in common language applied to any ore from which iron can be extracted, though by geologists it is usually restricted to the carbonate of iron which is found in layers or nodules among sedimentary strata, the others being termed iron-ores. Two varieties of ironstone are found in the districts illustrated by the foregoing Collection :—1. *Clay-band* ironstone, and, 2. *Black-band* ironstone.

Clay-band is a mixture in variable proportions of carbonate of protoxide of iron, with clay, sand, and other impurities. It occurs as beds, varying in thickness from a mere film up to two feet or more, which lie among the shales of the carboniferous formation, and as oblong or irregular nodules in the shales and fireclays. These ironstones contain on an average from 25 to 35 per cent. of metallic iron. Blackband is merely clay-band, in which so much carbonaceous matter has been enclosed, that the stone requires little or no coal to be added for the process of calcining. These ironstones have been deposited along with muddy sediment and vegetable remains in shallow water during the accumulation of the carboniferous rocks.

Hæmatite, or red-iron ore (anhydrous sesquioxide of iron), is found in thin veins among the trap rocks of the Lothians. A workable lode has recently been opened among the porphyrites of the Garlton Hills.—(See Case 21, No. 11.)

Lapilli (I).—The name given to the smaller stones or gravel ejected from a volcano.

Limestone (A).—A rock consisting almost wholly of carbonate of lime, and in most cases derived from the accumulation of shells, corals, or other animal remains. In Window Case 27, Nos. 130 to 141, are specimens of limestone formed probably from the remains of minute crustaceans in brackish water. In Window Case 21, Nos. 41–45 illustrate limestones made up of shells, corals, encrinites, and other marine animal remains. Nos. 184, 185, Window Case 28, were probably deposited by the intermittent action of a hot spring, which was charged with lime and silica.

Lydian-Stone (M).—A very compact flinty form of altered shale or slate, usually of black colour.

Melaphyre (I).—Under this name are included in the Collection dark basic rocks, which occur both as intruded and as contemporaneous masses in the Old Red Sandstone, Carboniferous, and Permian formations. They are closely allied to the doleritic group, and pass insensibly into it; the chief differences between them arising, perhaps, from a greater degree of alteration in the melaphyres. The latter rocks, as a rule, have a more compact base, and duller texture; the augite in them is more altered, the iron less in quantity, and the specific gravity not so great. But both by chemical and microscopic analysis, we learn that there is the closest affinity in origin, texture, and composition, between true doleritic or basaltic rocks and these so-called melaphyres. In certain districts, as near Bathgate, the melaphyres contain a considerable quantity of a green chloritic colouring matter, and then pass into rocks which answer in many respects to the *diabase* of continental petrographers.

Micaceous.—Full of the mineral known as *mica.*

Minette (I).—A rock having a compact felsitic base, through which abundant spangles of mica are scattered, with sometimes hornblende and other minerals.

Mudstone (A).—Mud or sandy clay, not laminated, but hardened into stone.

Pectolite.—A mineral (silicate of lime and soda) which occurs in white fibrous aggregations.—(See No. 57, p. 53.)

Porphyrite (I).—When a rock consists essentially of a felspar base (usually labradorite or oligoclase), to which are added a greater or less proportion of felspar crystals, and sometimes other minerals, it is called porphyrite. Such rocks vary in colour from almost white, through many tints of red and brown to dark tints, like those of the melaphyres. When the proportion of augite and titaniferous iron increases, the porphyrite passes into rocks which cannot be distinguished from melaphyres. The greater mass of the Pentland Hills consists of varieties of porphyrite; so also the Garlton Hills. The porphyrites in the Collection are all older than the Carboniferous Limestone series.

When porphyrite is much decomposed, it passes into a rock formerly called 'claystone.' The more compact varieties have been called *clinkstone,* from the metallic sound they give out when struck. But that name is now restricted to the more siliceous felspar rocks or phonolites. 'Compact felspar' was the name formerly given to many of the porphyrites of the Pentland Hills. They have also been called 'felstones;' but it is desirable to reserve that term for the less basic forms of felspar rocks.

Porphyry (I).—Strictly speaking, the word porphyry describes a kind of texture common to many varieties of igneous rock. When a rock has distinct crystals, usually of some felspar, scattered through its base, it is a *porphyry.* The term, however, is sometimes applied to some of the acidic felspar rocks, where the *porphyritic* texture is very characteristic. Thus we have *felspar porphyry, quartz porphyry, hornblendic porphyry,* etc.

Quartz.—A mineral consisting of pure silica. When a rock consists mainly of quartz, it is said to be quartzy, or quartzose; when an igneous rock, such as a porphyry, contains blebs or specks of quartz, it is called *quartziferous.* A sandstone which has been *metamorphosed* is called a *quartz-rock.*

Sandstone (A).—Sand which has been compacted into stone. Sandstone consists mainly, sometimes almost entirely, of small water-worn grains of quartz. Various varieties of sandstone are distinguished by builders and miners *Freestone* is a sandstone in which the stratification does not prevent the rock from being freely dressed or cut and sculptured for architectural purposes. Some kinds of freestone are known as *liver-rock,* when they can be quarried in blocks of any size and shape. *Fakes* is the name given in Scotland to those varieties of sandstone which are so laminated as to pass by degrees into shale. *Fakey sandstone* is an intermediate stage between ordinary freestone and fakes.

Schist (M).—A metamorphic rock, having a tendency to split along wavy divisional plains, which run more or less parallel to each other. Such a rock has been originally of sedimentary character, such as a clayey sandstone or shale, and has been altered or *metamorphosed* by underground agents into its present state. Schists receive various names, according to the prevalent or distinguishing mineral in them, as mica-schist, talc-schist, etc. The peculiar fissile structure of a schist gives rise to the term *schistose.*

Serpentine (M).—A term applied both to a mineral (a hydrous silicate of magnesia) and to a rock composed of that mineral. There is reason to believe that serpentine is always the product of metamorphism.

Shale (A).—A hardened laminated clay rock, which can be split into laminæ. It has originally been deposited as fine mud in successive layers. It varies much in composition. Sometimes it is sandy, and passes into sandstone; sometimes limey or calcareous, shading into true limestone; sometimes bituminous, and then passing into certain varieties of coal. It is bituminous shale from which oil has been so extensively distilled in this country during the last few years.

Hence in Scotland, among those engaged in mining, the word *shale* has come to be used as equivalent to *oil shale* or bituminous shale, while the shales which do not yield oil are by the miners termed *blaes.*

Syenite (I and M).—A crystalline rock consisting of orthoclase, hornblende, and quartz. The German petrographers, however, exclude from the term syenite all the rock into which quartz distinctly enters.

Trap (I).—Under this term are commonly included all the ordinary igneous rocks which do not belong to the granite family. Melaphyre, basalt, porphyrite, dolerite, trap-tuff, are trap or trappean rocks. The word trap is derived from the Swedish, and was first used as descriptive of the step-like outline which many hills formed of these rocks present. The term, however, is so vague that it is falling out of use.

Trappean (volcanic) Agglomerate (I).—This name is applied to unstratified masses of coarse volcanic detritus, which, throughout a considerable part of the midland valley of Scotland, rise in 'necks' or large pipe-shaped protrusions through the Carboniferous rocks. These necks are regarded as probably marking the actual position of former volcanic vents, and the agglomerate as the coarse rubbish which, after being thrown up from an orifice, fell back into it and finally solidified there. The materials of which the agglomerates are made up constantly vary, according to the nature of the rocks through which the hole was driven, and of those which existed at the time in a melted state beneath.

Trappean (volcanic) Conglomerate (I and A).—When a tuff loses much of its fine matrix, and becomes chiefly made up of rounded fragments of trappean rocks, it is called conglomerate. Such conglomerates have probably been often formed by the denudation of solid trap-rocks, exposed either to rivers or wave action, and are in that respect not truly of volcanic origin. Others have been accumulated where volcanic action was going on, and are so associated with tuffs and other volcanic rocks, that they cannot properly be separated from the volcanic series. When the fragments are angular instead of round, the rock is styled a breccia.

Tuff, Trap-tuff or **Ash** (I and A).—Under this term are included all the finer varieties derived from showers of volcanic dust and small stones, and in some cases perhaps from the denudation of previously formed trappean rocks. The volcanic materials differed at the time of eruption according to the nature of the rock from whose trituration they had been derived. Hence, if the rock which was blown into dust by the volcanic explosions was melaphyre, its assorted debris went to form *melaphyre-tuff;* if porphyrite, it formed *porphyrite-tuff.* It has happened, however, in many cases, that from subsequent alteration, or from some other cause, it is now difficult to tell what the original rock was from which the tuffs were derived. In the present Collection the tuffs are divisible into two groups:—The *melaphyre-tuffs* or *dolerite-tuffs,* usually of a dull dirty green, and evidently derived from the dark basic rocks (melaphyres, dolerites, etc.), and the *porphyrite-tuffs* or *felspathic-tuffs,* commonly lighter in colour, frequently red or grey, and associated with the porphyrites from which they have no doubt been formed.

When a sandstone or other sedimentary rock becomes charged with the dust or stones of which the tuffs consist, it is said to be *ashy* or *tuffaceous.*

Vesicular.—See *Amygdaloid.*

'White Trap' (I).—A form assumed by basalt and dolerite when they come in contact with coal or bituminous shale.—(See 242 in Window Case 29, and Catalogue, p. 81.)

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